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Determination of the Mineral Volumes for the Pre-Cenozoic Magmatic Basement Rocks of Cửu Long Basin from Well log Data via Using the Artificial Neural Networks

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Abstract: The mineral volumes in the magmatic basement rocks are the most important characteristics in investigation of the oil bodies in fractured basement rocks and during the production process. The BASROC software can be used for calculation of the mineral volumes with great accuracy only when adequate and virtuous well log curves can be obtained. In fact, this requirement is very difficult to attain in [1].

This study offers a method, which can be used for calculation of the Mineral volumes of the Pre-Cenozoic Magmatic basement rocks of Cửu Long basin from Well log data by using Artificial Neural Networks. Firstly, by using the mineral volumes of a well that the BASROC software could calculate with great accuracy for network instruction, then the neural system can calculate the wells which the BASROC software could not analyz**e** due to bad quality and/or insufficient well log curve datas.

The testing results on the wells, calcultated by the BASROC software and the mineral volumes calculations in reality in order to build the mining production technology diagrams (according to the contract about the joint study between PVEP and JVPC) show that the Artificial Neural Network model of this research is a great tool for determining the mineral volumes.

Keywords: ANN, determination, mineral volumes, Magmatic basement rocks, Cửu Long basin, Artificial Neural Networks, ANN in oil and gas industry, well log data.

1. Introduction

The oil body in the fractured Pre-Cenozoic basement rocks of the White Tiger (extension 1500 meters thick) is one of the exceptional oil bodies in the planet. The geological development features and the oil-bearing rock distribution have some unique features, controlled by rock formation mechanism and its characteristics. These specific features created serious difficulties for the porosity and mineral volume investigation. [1]

According to previous studies, the pre-cenozoic basement rocks of Cuu Long basin is consisted of 5 components:

Albite (Plagioclase) , abbreviated by a
Biotite (Mica group), abbreviated by b
Hornblend amphibol, abbreviated by h
Orthoclase K-feldspar, abbreviated by o
Quartz, abbreviated by q

Their volumes are: V_a, V_b, V_h, V_o, V_q where:

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$$\varphi + V_a + V_b + V_h + V_o + V_q = 1 \quad (1)$$

The mineral volumes in the fractured basement rocks can not be measured by sampling because rock samples would be destroyed after being brought to the surface. The BASROC software can only calculate the mineral volumes under some specific conditions, for example, when the well log data are complete and have a good record collection. And for this, experienced experts are required to select the necessary mineral parameters to handle. These conditions are very difficult to meet in practice. Many foreign contractors (such as JVPC, etc.) usually face some difficulties in calculating the mineral volumes. Therefore, figuring out a new method to improve the quality of mineral volume calculation is urgently needed.

Approach:

Because BASROC software cannot solve the above problem completely, this research has developed the Artificial Neural Network (ANN) method to solve the math problem in calculating the mineral volumes.

Objective

The main objective is to determine (with adequate accuracy) the mineral volumes of the basement rocks when the well log data are not complete and/or the material is of bad quality as usually found today.

The porosity and permeability calculations have been completed by some authors [2-4] for the specific oil fields on the basis of data collected by sampling methods. However, by now no research work has been done on the mineral volume calculation.

Database:

The actual data usually allow to get to 6 or 7 curves: GR, DT, NPHI, RHOB, LLD, LLS ... as shown in the following table:

	Depth	GR (API)	DT (μ s/fit)	NPHI (dec)	RHOB (g/cm3)	U (ppm)	LLD (Ohm.n)	LLS (Ohm.m)
1	3312.8700	56.5800	53.9900	0.0620	2.6700	12.6200	1013.2000	436.0000
2	3313.0200	54.0500	53.4700	0.0590	2.6900	12.7100	1159.7000	463.3000
3	3313.1800	51.5200	52.9400	0.0550	2.7100	12.8100	1306.3000	490.7000
4	3313.3300	48.9900	52.4200	0.0520	2.7300	12.9000	1452.8000	518.0000
5	3313.4800	46.4600	51.8900	0.0480	2.7500	12.9900	1599.4000	545.3000
6	3313.6300	43.9400	51.3700	0.0450	2.7600	13.0900	1745.9000	572.7000
7	3313.7900	41.4100	50.8400	0.0410	2.7800	13.1800	1892.5000	600.0000
8	3313.9400	44.3300	50.9300	0.0350	2.7600	12.6300	1842.9000	579.5000
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
5771	4192.2200	122.4900	51.6100	0.0280	2.5900	9.8100	-999.0000	-999.0000
5772	4192.3700	122.4900	51.7300	0.0290	2.5900	9.9500	-999.0000	-999.0000

Nevertheless, the data collected from the roof to the bottom of the well, rarely are adequate and good enough to fully satisfy the calculating conditions of the BASROC software.

From the top to bottom of the wells, many intervals of recorded curves have been broken, and mostly only 4 to 5 curves have been recorded. The actual obtained data are difficult to meet the requirements of the BASROC software, however, these data easily meet the requirements of the artificial neural network method.

2. Overview of the BASROC Software and Artificial Neural Network:

2.1. The BASROC Software

The Project: "Research on technology solutions to estimate the reserve and design the mining production technology diagrams in the fractured basement rocks by BASROC software" is the collective research work completed by a group of seven authors led by Dr Hoang Van Quy. The Russian Federation acknowledged this software for researching and operating mining of VSP. This research is on par with other solutions in the oil industry around the world and has gained the WIPO Award and VIFOTEC-2006 Award.

The determination of mineral volumes is one of the four main modules in this software. When the recorded well log data are sufficient and good enough, has experienced specialists selected for the mineralogical parameters and treatment, the results would come out with greate accuracy. Many theory review and practice have identified this. However, this condition is very difficult to meet in reality. Therefore, the BASROC software almost could not meet the actual requirement. This is the reason why this research has selected the Artificial Neural Network method.

2.2. Artifical neural Networks (ANN)

The Artifical neural Networks-ANN is the mathematical model of the biological neural Networks to solve a specific math problem.

By connecting Input and Output of the neurals together, we would have a neural network [5]

In the network, the neurons are distinguished by its location, specifically:

Input layer: The neurons receive information from outside the network. They are located outside the "left" and communicate with other neurons of Hidden layer.

Output layer: Group of the neurons are connected to other neurons through the neurons of Hidden layer. They stay in the position outside the "right" to translate the signal to the outside.

Hidden layer: The remaining neurons that are not belong to any of the two above layers

The Network is divided into layers. The neurons in the same layer have the same function

The Neural network can consist of multiple hidden layer, however LiminFu [6] (1994) demonstrated that only one hidden layer is sufficient to model any function. So the networks only need three layers (Input layer, Hidden layer and Output layer) to operate.

The following Figure is an Artifical neural, which includes R Input : $p_1, p_2 ...... p_R$ and 1 output [7]

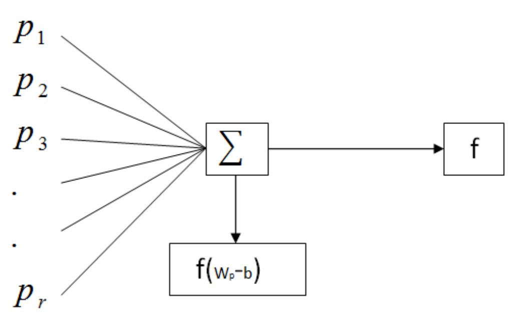


Figure 1. an Artifical neural model.

Network Development:

In this study, the authors develop the artificial neural network consists of 3 layers [6]:

- Input layer consists of n neurons: $x_1, x_2, ...x_n$,

- Hidden layer of k neurons and the transfer functions $f_j(x)$ with $j = 1,2...k$

- Output layer consists of m neurons and the transfer functions $F_l(x)$ with $l = 1,2,..,m$

Each neuron is a unit of account with many Inputs and one Output [5]. Each neuron has an energy of its own called its bias level, and it receives the energy from other neurons with different intensity as the corresponding weight.

Neuron j of the hidden layer has the bias threshold is ω_{Hj} , the value of Neuron j of the hidden layer receive from the Input layer is $\sum_{i=1}^{n}\omega_{ij}^{1}.x_i$ [5] So it's value is $\omega_{Hj} + \sum_{i=1}^{n}\omega_{ij}^{1}.x_i$, where ω_{ii}^{1} are weight.

With the transfer function $f_j(x)$, So it's value will output is $f_j(\omega_{Hj} + \sum_{i=1}^{n}\omega_{ij}^{1}.x_i)$

This value is sent to the Output neurons l with $l = 1,2,..,m$ and with weights ω_{jl}^{2}, So the value of neuron l of the Output layer is $b_{ol} + \sum_{j=1}^{k}\omega_{jl}^{2}.\mathrm{f_j}(\omega_{Hj} + \sum_{i=1}^{n}\omega_{ij}^{1}x_i)$, where b_{ol} is the bias threshold of the Output neuron l.

With Transfer function $F_l(x)$, So the value of the neurons l of the Output layer will out of is:

$$y_l = F_l(b_{ol} + \sum_{j=1}^{k}\omega_{jl}^{2}.f_j(\omega_{Hj} + \sum_{i=1}^{n}\omega_{ij}^{1}x_i)) \quad (3)$$

with $l = 1,2,...k$

In this study, transfer function: $F_l(x) = f_j(x) = \tan sig(x)$ with $x \in [0;+\infty)$, So the formula (3) takes the form:

$$y_l = f(b_{ol} + \sum_{j=1}^{k}\omega_{jl}^{2}.f(\omega_{Hj} + \sum_{i=1}^{n}\omega_{ij}^{1}x_i)) \quad (4)$$

with $l = 1,2,...k$

in which: $f(x) = \tan sig(x)$

This value in the training process is compared with the target value to calculate the error. In the calculation process, this value will be out.

Back-propagation algorithm [8] was used to train network.

Error function is calculated by using the formula [9]:

$$Ero = \frac{1}{p}\sum_{i=1}^{p}\left(O_i - t_i\right)^2 \qquad (5)$$

Training Network:

Definition 1:

The training well is the well that their well log curves and ϕ , Va, Vb, Vh, Vo, Vq are known. It was used to train the Artificial Neural Network

The Initial training well is the well that their well log curves are known and ϕ , Va, Vb, Vh, Vo, Vq was calculated by BASROC software. It was used to train the Artificial Neural Network

The secondary training well is the well that their well log curves are known and ϕ , Va, Vb, Vh, Vo, Vq was calculated by the Artificial Neural Network. It was used to train the

Artificial Neural Network to calculate another well. (Fulfill the matching principle)

Definition 2:

The calculated wells are the wells only known their well log curves, and unknown ϕ, Va, Vb, Vh, Vo, Vq. We need calculate ϕ, Va, Vb, Vh, Vo, Vq by using the Artificial Neural Network method.

The training set must be selected spans from the roof of the foundation to the bottom of the well. We selecte as follows:

Select the t^{th} row of the training well with t = 10.i - 9 with i = 1,2,3, ..., 360. We receive the training set.

The Input columns are sent to the Logs matrix, the columns: ϕ ,Va, Vb, Vh, Vo, Vq are sent to the TARGET matrix, We have the training set of the form (Logs, TARGET).

Standardization of data:

GR, DT, NPHI, RHOB are standardized by using the Div (X) coefficients:

$$Div(X) = \frac{\max(X)}{k} \quad \text{with} \quad k \in [0.70 \quad 0.95] \tag{6}$$

LLD, LLS are standardized by the average formula: the standardized value $x_{S\tan d}$ of x :

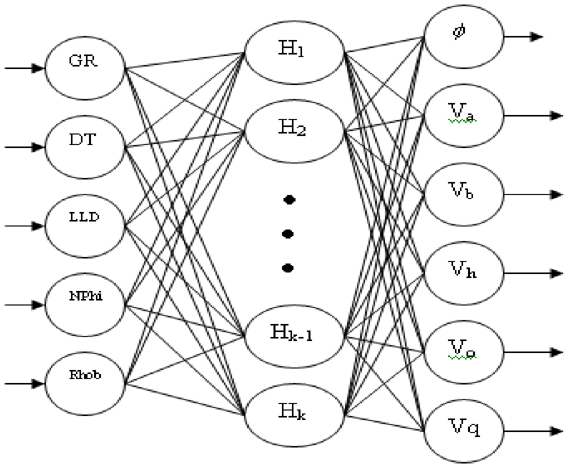
$$x_{S\tan d} = \begin{cases} \dfrac{x}{2 * mean(X)} & if \quad x \le mean(X) \\ \dfrac{1}{2} + \dfrac{x - mean(X)}{2 * (\max(X) - mean(X))} & if \quad x > mean(X) \end{cases} \tag{7}$$

Matching principle:

The Matching principle: The calculated well must be consistent with the training well. That is, the Div (X) coefficients and the parameters in the formula of average values of the calculated well must be coincide with these values of the training well.

The Artificial neural network to calculate the mineral volumes :

With 5 Input: GR, DT, LLD, NPHI, RHOB, and 6 Output: ϕ, Va, Vb, Vh, Vo, Vq, The network is designed as follows:



Use HV_1J_Ha. well to train the network.

The Mean square error after training the network is: 0.00004237.

The calculated network :

After training the network, we have two steps to calculations for a calculated wells as follows:

- First step: Calibration coefficients Div(X) and the parameters in the formula of the average value of calculated well that these values must match the corresponding value of the Training well.

- Second step: Give input of the Calculated well into the net, the net will automatically calculate the mineral volumes of the calculated well

In the Appendix, have the results in calculated the mineral volumes for well HV_5J (Table 1)

Along with calculation the mineral volumes, we also have the software to calculate own porosity. The values of two porosity are identical. This confirm the accuracy of both methods of calculation (see column 5 and column 6 Table 2).

The Correction of the Result

Use the equation : $\phi + V_a + V_b + V_h + V_o + V_q = 1$ to correct the result :

Set: $x_1 = \phi$; $x_2 = V_a$; $x_3 = V_b$; $x_4 = V_h$; $x_5 = V_o$; $x_6 = V_q$

Set : $sum = \sum_{i=1}^{6} x_i$ Set : $lech = 1 - sum$

Set : $\overline{x_i}$ is the value correction of x_i so the formula for calculating the correction value as follows:

$$\bar{x}_i = x_i + \frac{(x_i * lech)}{sum} \text{ with } i = 1,2....6 \qquad (8)$$

So we have: $\sum_{i=1}^{6} \bar{x}_i = 1$.

$$\sum_{i=1}^{6} \bar{x}_i = \sum_{i=1}^{6} \left[x_i + \frac{(x_i * lech)}{sum} \right] = \sum_{i=1}^{6} x_i + \frac{lech}{sum} * \sum_{i=1}^{6} x_i = sum + lech = 1 \quad . \qquad (9)$$

When we calculated *sum* for all of the line of the wells, we see that the value of *sum* in all lines have a trend or approximately 1.1 or approximately 0.92 . This means that the value calculated should be corrected for 1.

3. Results

From basic research and practical experience of handling 19 wells, this research has developed a system of programs (MATLAB language) and offer the rule of processing for the problem.

Check series wells that the BASROC software calculated and the wells were calculated by the other software show that: The results of this study are very accurate , can be applied in practice.

The first applying of this research is to calculate for 19 wells of JVPC. The results are as follows:

- The BASROC software only can calculate 4 wells, including well HV_1J_Ha be used to train the network

- The Artificial neural network of this study uses well HV_1J_Ha to train the network .After training, the network was used to calculate the remaining 18 wells. The results are good for 18 wells, like the HV_5J well give in the Appendix (Table 1).

- JVPC used this result to develop the mining production technology diagrams.

Figure 1 to Figure 7 show the correlation between the results from the neural network and the results of BASROC (Used as input to train the neural network).

Table1: The result of the calculation mineral volumes for the Calculated wells HV_5J.

4. Conclusion

1. The problem of calculation the mineral volumes is good with 5 Inputs are: GR, DT, RHOB, LLD, LLS or 6 Inputs are: GR, DT, NPHI, RHOB, LLD, LLS.

2. The training set should select *p* from 300 to 400 as well. Do not choose more.

3. The results of this study can be used both in basic research and in practical calculations to develop the mining production technology diagrams.

4. ANN network model of this study to calculate the mineral volumes with great accuracy is due to:

- Use a well that BASROC calculated, this study has developed the appropriate training set for each calculated well.

- The standardization methods of this study is accuracy.

- This study find out the Matching principle and comply this principle.

- Use formula (1) to calibrate and test results of the accuracy of the Div (X) coefficient and standardized averages formula.

5 . ANN network model of this study can be applied to other calculations in the research the oil body of White Tiger

Acknowledgments

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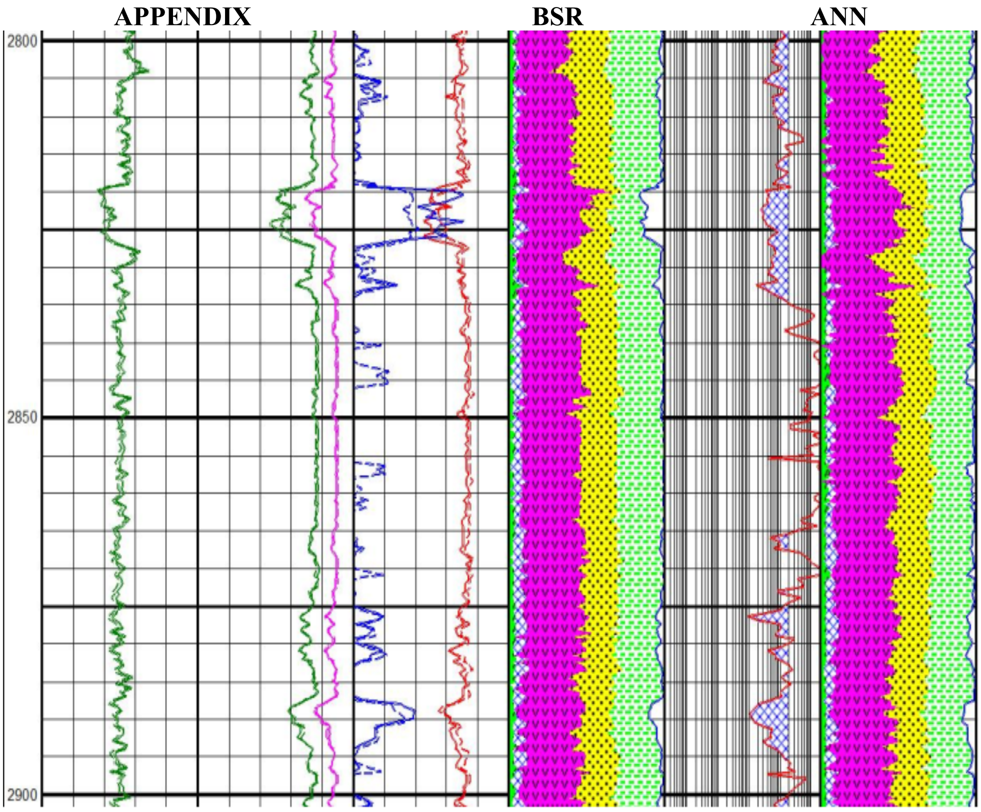

Figure 1. Calculate ϕ & The mineral compgnents by **BSR**(left) and by **ANN** (right).

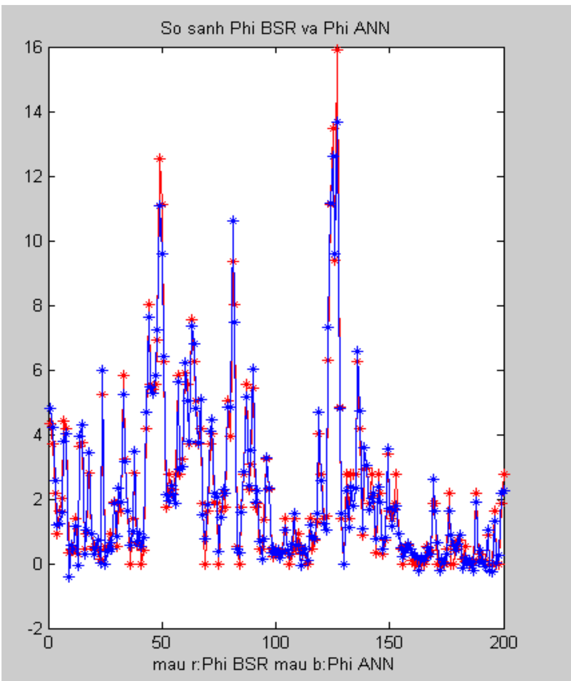

Figure 2. Comparing ϕ.

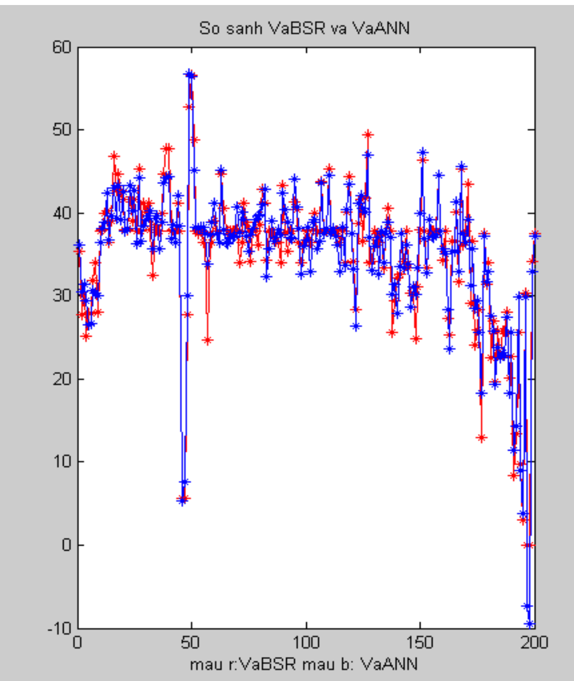

Figure 3. Comparing *Va*.

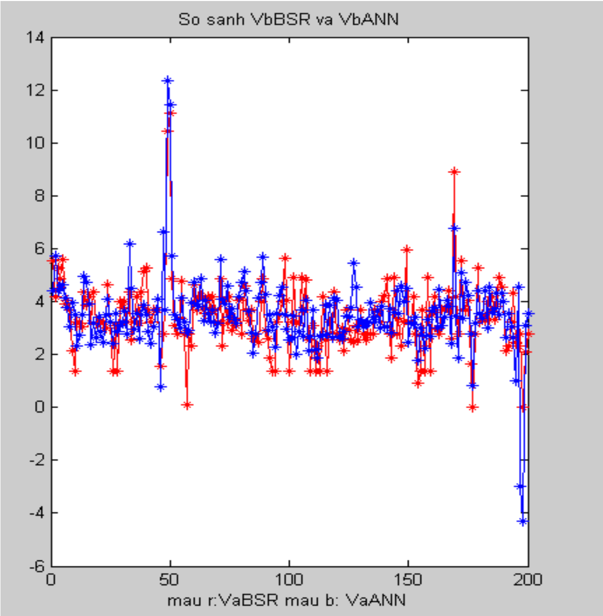

Figure 4. ComparingVb.

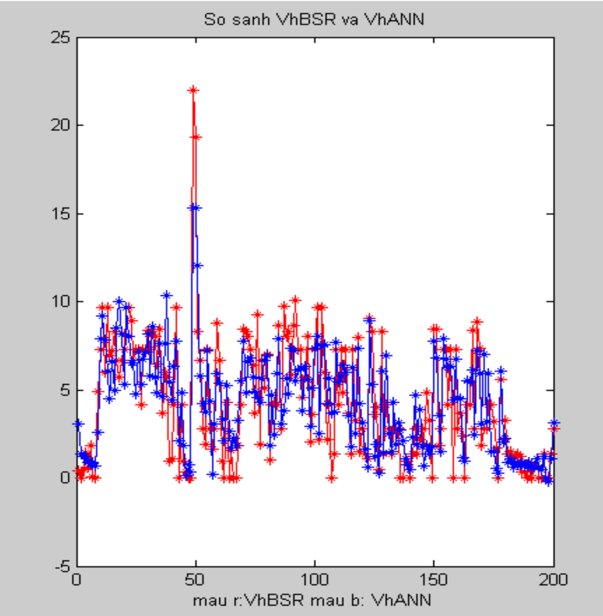

Figure 5. Comparing Vh.

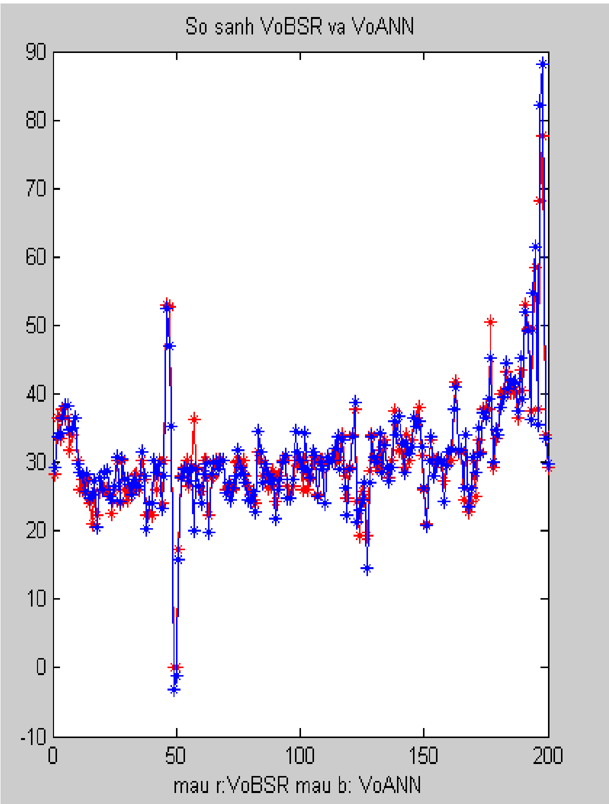

Figure 6. Comparing *Vo*.

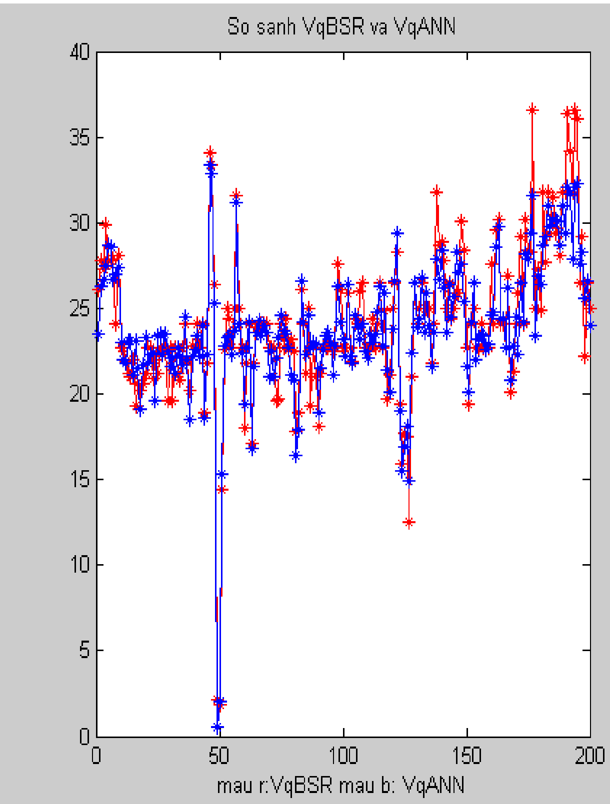

Figure 7. Comparing *Vq*.

Table 1. The mineral components the calculated well HV_5J.
Three first lines are wrong we denoted by -999

% Depth	Phi	Va	vb	Vh	Vo	Vq
3718.56010	-999.00000	-0.67000	0.35000	-0.28000	0.63000	0.36500
3718.71240	-999.00000	-0.67000	0.35000	-0.28000	0.63000	0.36500
3718.86500	-999.00000	-0.67000	0.35000	-0.28000	0.63000	0.36500
3719.01730	0.13070	0.61536	0.07900	0.09451	0.08913	0.11016
3719.16970	0.13053	0.61430	0.07945	0.09343	0.09057	0.11119
3719.32200	0.13107	0.61439	0.08700	0.09547	0.08219	0.10644
3719.47460	0.12986	0.60650	0.09343	0.09138	0.08729	0.11005
3719.62700	0.13039	0.61222	0.08690	0.09544	0.08499	0.10772
3719.77930	0.13190	0.62529	0.06715	0.10369	0.08280	0.10448
3719.93160	0.13223	0.62696	0.06621	0.10558	0.08046	0.10282
3720.08400	0.13104	0.61785	0.07981	0.09908	0.08313	0.10580
3720.23660	0.13292	0.62792	0.07053	0.10615	0.07437	0.09965
3720.38890	0.13332	0.63073	0.06345	0.10663	0.07610	0.10049
3720.54130	0.13277	0.62835	0.06335	0.10304	0.08152	0.10418
3720.69360	0.13064	0.61415	0.08063	0.09318	0.08980	0.11092
3720.84620	0.12945	0.60612	0.08745	0.08879	0.09491	0.11463
3720.99850	0.12991	0.60937	0.08574	0.09133	0.09151	0.11220
3721.15090	0.12783	0.59317	0.09904	0.08369	0.09958	0.11832
3721.30320	0.12772	0.58978	0.10600	0.08407	0.09556	0.11617
3721.45580	0.12918	0.59612	0.11273	0.09077	0.07890	0.10587
3721.60820	0.12979	0.60184	0.10959	0.09514	0.07416	0.10219
3721.76050	0.12973	0.60866	0.11027	0.10199	0.05690	0.09100
3721.91280	0.13243	0.61540	0.08472	0.09895	0.09125	0.11071
3722.06520	0.13556	0.63287	0.05791	0.11054	0.09241	0.10920
3722.21780	0.14077	0.65066	-0.00073	0.12523	0.12739	0.12689
3722.37010	0.13967	0.64919	0.00544	0.12597	0.11861	0.12133
3722.52250	0.14012	0.65159	-0.01370	0.13066	0.13533	0.12955
3722.67480	0.13876	0.64475	-0.00318	0.11749	0.15021	0.13962
3722.82740	0.13775	0.63280	0.01481	0.09972	0.17015	0.15362
3722.97970	0.13790	0.63492	0.00735	0.10029	0.17281	0.15486
3723.13210	0.13545	0.61876	0.02703	0.08792	0.18235	0.16155
3723.28440	0.13259	0.59595	0.04618	0.07510	0.19232	0.16850
3723.43700	0.13263	0.59754	0.04369	0.07590	0.19253	0.16837
3723.58940	0.13213	0.59506	0.04422	0.07596	0.19456	0.16927
3723.74170	0.13060	0.58206	0.04801	0.06745	0.20519	0.17613
3723.89400	0.12815	0.56920	0.03995	0.05764	0.22439	0.18705
3724.04640	0.12709	0.56103	0.04053	0.05351	0.23104	0.19102
3724.19900	0.12844	0.54422	0.07901	0.05641	0.20996	0.18120
3724.35130	0.12641	0.50139	0.10555	0.04869	0.21308	0.18476
3724.50370	0.12653	0.49612	0.11245	0.04920	0.20880	0.18271
3724.65600	0.12746	0.53359	0.08321	0.05408	0.21237	0.18266
3724.80860	0.12910	0.55247	0.07816	0.06081	0.20264	0.17651
3724.96090	0.13005	0.54639	0.09608	0.06209	0.19134	0.17137
3725.11330	0.12748	0.48370	0.13379	0.05122	0.19401	0.17583
3725.26560	0.12574	0.45884	0.13640	0.04568	0.20501	0.18236
3725.41820	0.12480	0.45465	0.13203	0.04405	0.21019	0.18475
3725.57060	0.12313	0.44047	0.12774	0.03973	0.22128	0.19069
3725.72290	0.12320	0.43323	0.13208	0.03889	0.22187	0.19153
3725.87520	0.12436	0.46820	0.11595	0.04265	0.22075	0.18976
3726.02760	0.12173	0.44228	0.11349	0.03596	0.23545	0.19782
3726.18020	0.12239	0.43789	0.12278	0.03768	0.22791	0.19414
3726.33250	0.12020	0.42148	0.11520	0.03177	0.24384	0.20267
3726.48490	0.12689	0.52783	0.08133	0.05050	0.22011	0.18733
3726.63720	0.12546	0.50206	0.09011	0.04326	0.23262	0.19554
3726.78980	0.13050	0.53007	0.11337	0.05695	0.19501	0.17619
3726.94210	0.13458	0.57525	0.10860	0.07321	0.16049	0.15579
3727.09450	0.13450	0.57122	0.11720	0.07407	0.15264	0.15147
3727.24680	0.13728	0.61175	0.08011	0.09167	0.14275	0.14201
3727.39940	0.13672	0.61699	0.05358	0.09132	0.16122	0.15094
3727.55180	0.13873	0.63973	-0.00143	0.10423	0.17058	0.15320
3727.70410	0.13821	0.63595	0.00741	0.10094	0.17092	0.15391
3727.85640	0.13935	0.63783	0.02408	0.10762	0.15142	0.14313
3728.00880	0.13906	0.63721	0.01995	0.10553	0.15678	0.14618
3728.16140	0.13762	0.63167	0.01313	0.09540	0.17494	0.15703
3728.31370	0.13654	0.62991	-0.00164	0.08884	0.19179	0.16640

Xác định thành phần thạch học cho đá móng Macma trước Kainozoi bể Cửu Long từ tài liệu địa vật lý giếng khoan bằng mạng Nơron nhân tạo

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Tóm tắt: Thành phần thạch học trong đá móng Magma là đặc trưng rất quan trong trong nghiên cứu thân dầu trong đá móng nứt nẻ và trong thực tế khai thác. Phần mềm BAROC chỉ tính được thành phần thạch học với độ chính xác cao với điều kiện tài liệu địa vật lý giếng khoan phải thu đầy đủ và tốt. Điều kiện này rất khó đáp ứng trong thực tế [1].

Nghiên cứu này đưa ra phương pháp xác định thành phần thạch học cho đá móng Macma trước Kainozoi bể Cửu Long từ tài liệu địa vật lý giếng khoan bằng mạng nơron nhân tạo (ANN). Sử dụng kết quả của một giếng mà phần mềm BAROC tính được thành phần thạch học để huấn luyện mạng rồi sau đó mạng nơron nhân tạo sẽ tính cho những giếng mà BASROC không tính được vì tài liệu địa vật lý giếng khoan không đầy đủ và chất lượng xấu.

Kết quả kiểm tra những giếng tính được bằng phần mềm BASROC và tính toán thực tế để xây dựng sơ đồ công nghệ khai thác mỏ cho thấy: Mô hình mạng nơron nhân tạo (ANN) của nghiên cứu này là công cụ tốt để xác định thành phần thạch học.

Từ khóa: ANN, xác định, thành phần khoáng vật, đá móng magma, bồn trũng Cửu Long, mạng Neural nhân tạo, ANN trong dầu khí, địa vật lý giếng khoan.