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DETERMINATION OF THE INFLUENCE OF CA AND MG ON NEUTRON WELL LOG RESPONSE WITH MONTE CARLO MCNP SIMULATION

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ABSTRACT

This article is a study on simulating the influence of Ca and Mg on the behavior of neutron well log in various rock types and arrangement of the curves in various rock types and investigating the physical principle governed on this arrangement and also, determining the correct distance of detectors from neutron source for preventing of overlapping of the curves and, indicating the energy dependency of the neutrons in making the well logs curves and the placement of neutron detectors, to each other.

The simulation code of neutral particles by Monte Carlo method (MCNP) can be used for simulating the response of nuclear devices worked based on production and / or detection of neutral particles. In the present study, a model of thermal neutron probe has been simulated.

The results of this study indicate that for a ratio of near to far detectors counting, there is the lowest porosity in a dolomite environment and the middle porosity is in calcite environment and in a sandstone environment, the highest porosity. In other word, by drawing the calibration curves of all three environments in a chart, the dolomite curve is located in the lowest place and calcite curve is in the middle and sandstone curve is in the upper place of these two curves.

Physical principles governed on the behavior of calibration curves and also, the arrangement of placement of them in various environment to each other can associate with two components including, the ability of an environment for moderating neutrons in various energies, the neutrons moderating speed in various environments.

Also, the detector should be placed in proper distance from the source, depended on the neutron detected energy, to prevent the curve overlapping.

It is the first time to study the simulation of the influence of Ca and Mg in the behavior of neutron well log in a Naturally Fractured Gas-Condensate Reservoir in Khuff Formation (Kangan and Upper Dalan Formation) which is a heterogeneous formation.

Keywords: MCNP, neutron well log behavior, Ca and Mg influence, Monte Carlo method.

INTRODUCTION

Regarding the costs and present limitations in determining the reservoir characteristics through well test, well log generally is used for determining the reservoir characteristics. In order to study the behavior of well log device, especially nuclear well log in various conditions, the simulation of nuclear well log response in various conditions and different environments is required. Such a simulation is not available widely, because in one hand it requires awareness about information of designing nuclear well log and on the other hand, enough skill for simulating them through nuclear simulation devices like nuclear calculating simulation code, MCNP.

In this study, a general thermal compensated neutron well log has been simulated. This neuron well log has been simulated to have behavior like practical well logs and also determine the physical parameters governed on its behavior.

Neutrons interact with the materials within and around the well and sensitive detectors count the scattered neutrons. Porous formation may contain water, oil, gas or combination of them. The neutron well log includes a neutron source and neutron detectors that shield against neutron source, then, the respond of the detector is dependent on the formation porosity and its saturation with the oil and gas. Then, determining of the porosity, requires the necessary measurement for determining of the characteristics of materials around the well and presence of the water or oil or gas within formation porosities. These measurements are usually based on the performance of measurement tool in various conditions of the well and also receiving information from another well log tool [1].

Calculation of interacting nuclear particles in relevant matters to nuclear well log is very difficult, since they work in a 3-dementional space and particles penetrate in different depths, and scatter towards the detectors [2].

The result obtained from this study, cause the better understanding of the behavior of neutron well log in various conditions of formation and well, and determine some considerable points in designing and making of a neutron well log.

The neutron well log tool in this study has been simulated by calculating code of neutral particles of Mont-Carlo (MCNP) has published by Los Alamos laboratory. The history of the particles for solving equations of transferring particles has been simulated in a statistically space. Energy and the place of beginning of the neutrons movement from the source until the end of particle life time, for each particle, statistically is chosen from probability distribution function (PDF) to penetrating in to the formation and returning to detector [3].

MATERIALS AND METHODS

A well log curve is a graph against depth, supplies parameters and measured physical quantities in a well and derived parameters from them in from of curve. The simulated thermal neutron well log tool includes 2 Helium thermal neutron detectors and a 16 curie neutron source Am-Be. The distance between center of each detector and source and also their volumes are among important parameters of designing. A block of Boron Carbide is located between near and far detectors to not count the neutrons moved from the near detector and passed out of that by far detector. Also, a block of water and Boron Carbide is located between neutron source and near detector to prevent reaching the emitted neutrons from source to near detector. The set of the detectors, source and attractive blocks is located in an aluminum chamber and all of them are located in an iron cover [4].

Hydrogen has the most effect in neutron well log because when neutrons interact to Hydrogen nucleus, due to co-weighted with neutron, loses the most amount of energy, and have high collision cross section, too. In well log, when a neutron source, bombard the formation around the well with high-energy neutrons and high counting rate, a neutron cloud mass in circular from surrounds the source that radius of this neutron cloud changes with changing of the type of formation and existing hydrogen in formation. By increasing hydrogen in formation, more neutrons moderate and thus the detectors count reduce [5]

Neutron population especially thermal neutron population reduces by increasing distance from source. Usually counting in a neutron detector inversely is associated with the hydrogen amount of the formation. When the hydrogen content of the formation is high, more neutrons moderated and thus attract in formation, and when the hydrogen content of the formation is low, less neutrons attract to formation and thus, in relation to previous state, more neutrons reach to the detectors. The near detector count is more than the far detector count, and as result, near detector is better than far detector in statistical error. Instead, neutrons reached to near detector have more sensation to present elements in formation and for that reason, the far detector's behavior is more independent to present elements in formation than near detector [6].

Because, the elements constituting the formation are light elements and thermal neutrons detect, the most effective neutrons interaction with formation is respectively, elastic scattering and neutron absorption. The action of losing neutron energy is called neutron moderation and an element that caused losing energy is called moderator [7].

With regard to that the calibration curve of the well log tool is done in the type of calcite in various amount of porosity, after moving a well log in to a well, measuring the near and far detector count and obtaining their ratio and placing them in the calibration curve, the amount of porosity that results is related to the porosity into calcite. Now, if the formation around the well is other than calcite, for obtaining the porosity in that environment there needs to have matrix correction curve, to be able to do the necessary correction on obtained porosity, and obtain porosity in new environment [8].

Matrix correction curve, is resulted from the ratio of counting in near detector to far detector, when the type of the simulated environment and its porosity changes. Now, to examine the physical principle governed on these curves, there should be referred to the near and far detectors counting in each case.

Physical principle governed on the detectors counting can be classified in to two classes:

A. The neutrons moderating ability of various energies in various environments.

B. The neutrons moderating speed of various environments in various energies.

RESULT AND DISCUSSION

Because neutrons are neutral in electrical charge, then neutrons are not influenced by electron within atom and positive charge of atoms nucleus. Thus, neutrons pass from cloud of atom's electron and directly interact to atoms nucleus.

The quantity explained the rate of neutron interaction to nucleus, is called interaction cross section. Interaction of neutron to materials nucleus is in different forms, each of them have especial interaction cross section.

Another parameter used widely in nuclear engineering equations is macroscopic interaction cross section and show with symbol Σ. Macroscopic interaction cross section also can define for all kind of neutrons interaction like microscopic scattering interaction cross section ($\Sigma_s = N\sigma_s$).

Fig. 1, shows the matrix correction curve of porosity in neutron well log simulated by calculating code of MCNP4C.

Now, to determining the physical principle governed on these curves, there should be referred to the far and near detectors counting in each cases. From the counting of the simulated detectors in neutron well logs by simulating code of MCNP4C, there is observed that the near detector counting in sandstone is more than in dolomite and in dolomite is more than in calcite. Counting far detectors in each 3 cases is also similar to the near detector. Now, by examining the principal governed on these detectors counting, the physics governed on matrix correction curves will be reach.

The physical principles governed on the detectors counting can be classified in to two classes:

A. The neutrons moderating ability of various energies in various environments.

B. The neutrons moderating speed of various environments in various energies.

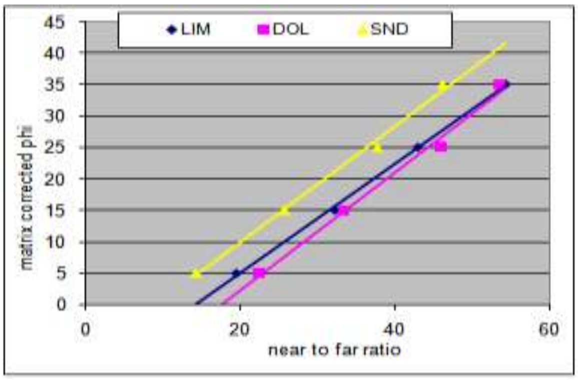

Fig. 1.Matrix correction curves

A. The neutron moderating ability of various energies in various environments:

One of the important parameters in moderating neutron in an environment is interaction cross sections of neutron in various energies with constituting elements of that environment. With regard to simulating results of MCNP4C about near and far detectors counting in various rock types that, the near and far detectors counting in sandstone are more than dolomite and in dolomite is more than calcite. Then, it is expected that moderating power in calcite is more than dolomite and in dolomite is more than sandstone.

Because of the light elements constitute calcite, dolomite and sandstone environment and also the thermal neutron is detected, then the most important neutron interaction includes elastic scattering interaction and absorption.

With the principals governed on neutron interaction cross section in interaction with molecules, the elastic scattering collision cross section is calculated and set in table 1 for several energies. According to table 1, elastic scattering cross section in dolomite is more than calcite and in calcite is more than sandstone which is the inverse of detectors count. Thus, this result indicates that the elastic scattering interaction can't be determinant of behavior neutron well log curves alone.

In the other hand, neutron absorption cross section in low neutron energies is more important than elastic scattering cross section, and also neutron absorption cross section affect on both moderating process and neutron counting, so the neutron absorption cross section should be compared in various environment especially in low energies.

With regard to chemical formulation of calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$), and also the way of producing dolomite, occurred by replacement of Mg with Ca, the difference of calcite and dolomite is in presence of Mg in dolomite instead of Ca in calcite.

Thus, according to molecule neutron cross section law, the difference between calcite absorption cross section and dolomite absorption cross section in different energies can be determined with difference in Ca absorption cross section and Mg absorption cross section. According to fig. 2, the neutron absorption cross section of Ca, is more than neutron absorption cross section of Mg, and this lead to that in various energies, the neutron absorption cross section of calcite is more than neutron absorption cross section of dolomite.

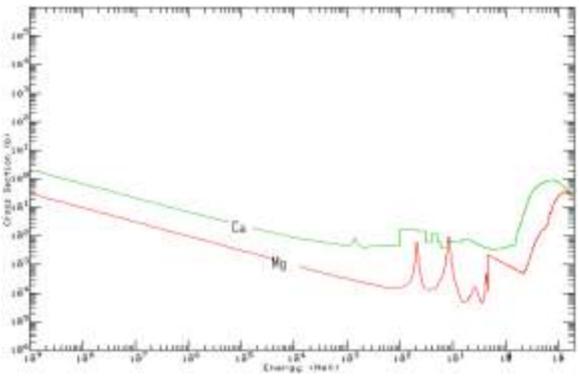

Fig. 2. Ca and Mg absorption cross section

So according to above, the valuable result is that in high energy neutrons, the scattering cross section in dolomite is more than calcite and in calcite is more than sandstone, and in low energies, absorption cross section in calcite is more than dolomite and in dolomite is more than sandstone. Therefore, the power of moderating in low energies in calcite is more than dolomite and in dolomite is more than sandstone, and in high energies, also the moderating power of dolomite is more than calcite and in calcite is more than sandstone. These are the main secret of neutron well log behavior.

The very important obtained result from the above is that by changing the detection neutron energy, the matrix correction curves arrangement will change. Now, this subject is confirmed by simulating code of MCNP4C.

In high detected neutron energy (fast and moderate energy), the detector counting in dolomite is less calcite and in calcite is less than in sandstone, because in this energy span elastic scattering interaction is more effective than absorption interaction, that it is admitted with above explanations (fig. 3).

In low detected neutron energy (epithermal and thermal energy), detector counting in calcite is less than in dolomite and in dolomite less than sandstone (fig. 4).

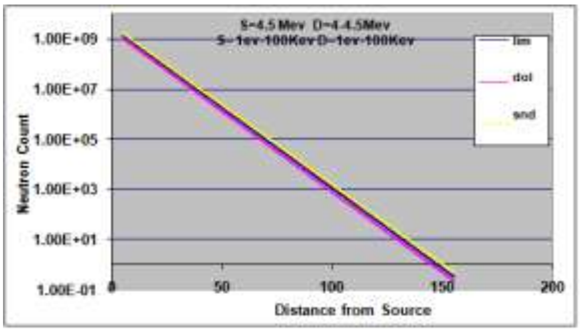

Fig. 3. Counted neutron by detectors in various distances between source and detectors in fast energy span in calcite, dolomite and sandstone environments

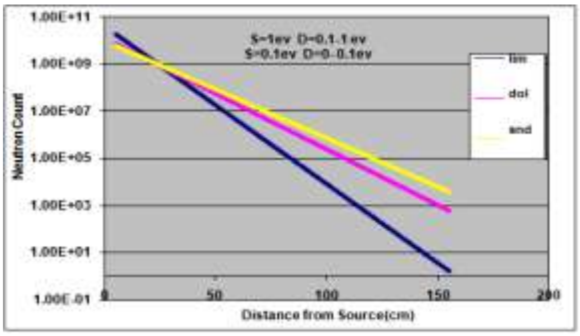

Fig. 4. Counted neutron by detectors in various distances between source and detectors in low energy span in calcite, dolomite and sandstone environments

A very important point exists in making neutron well logs is determination the precise place of the detectors (especially near detector) from neutron source. The reason of this is overlapping between obtained curves from neutron well log in certain distance between neutron source and the detector.

One the very important results from simulating neutron well log by MCNP4C code is determining overlapping distance in neutron well log. In fact, in overlapping distance, the curves arrangement displaced. This point is also important that by reducing neutrons energy, the overlapping distance increases.

B .The neutron moderating speed of various environments in various energies:

Since that simulating results of neutron well log through MCNP4C code in calcite, dolomite and sandstone environment are very near to each other so, examining the effective phenomena in detectors counting is also difficult. Now, for more precise consideration, the dependency of the detector distance from the source to energy spans is stated. Since, the near detector is in the distance of about 40 cm from neutron source, so it is logical that the number of the thermal neutrons in approximate distance of 35-45cm is effective in the detector counting. It is also true about epithermal neutrons, so that the number of present epithermal neutrons in 30-40cm is effective in thermal neutrons detector counting. In the case of neutrons with moderate energy, this distance is about 15-35cm. In the case of the fast neutrons this distance is about 5-30cm .So called distances in these energy spans, are called effective distance which influence on thermals neutrons detectors counting.

Moderating speed is also, one of the effective parameters in the near and far detectors counting. Increasing the hydrogen content of each environment cause to increase the moderating speed, and thus neutrons absorb from less distance to their source. In this stage, because of examining the physical principle on the matrix correction curve, the hydrogen content of calcite, dolomite and sandstone has been considered equal and only the rock type changes. Here, moderating speed has been appeared so that, in each environment that attracting of neutrons is done faster, or from less distance to source, that environment has higher moderating speed.

Now, the moderating speed of each environment is examined by MCNP4C. The MCNP4C result show that in high (fast and moderate) detected neutron energies, the moderating speed in calcite is more than in dolomite and in dolomite is more than sandstone (fig. 5, fig. 6).

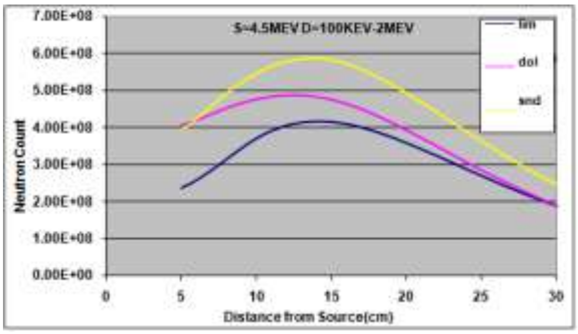

Fig. 5. Counted neutron by detectors in various effective distances between source and detectors in various energy span in calcite, dolomite and sandstone environments

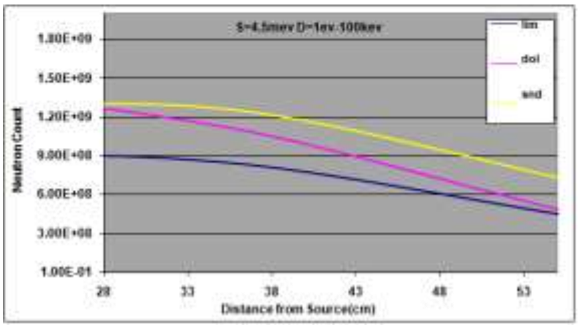

Fig. 6. Counted neutron by detectors in various effective distances between source and detectors in various energy span in calcite, dolomite and sandstone environments

There is concluded that in high energy span, the moderating speed in calcite is more than dolomite and in dolomite is more than sandstone but the moderating power in dolomite is more than calcite and in calcite is more than sandstone. One important result from this point is that if the neutron probe work according to detection of the neutron with energy near to source neutron energy, the probe curves change in some situation and the probe will be useless.

The MCNP4C result show that in low (epithermal and thermal) detected neutron energies, the moderating speed in calcite is more than in dolomite and in dolomite is more than sandstone (fig. 7, fig. 8).

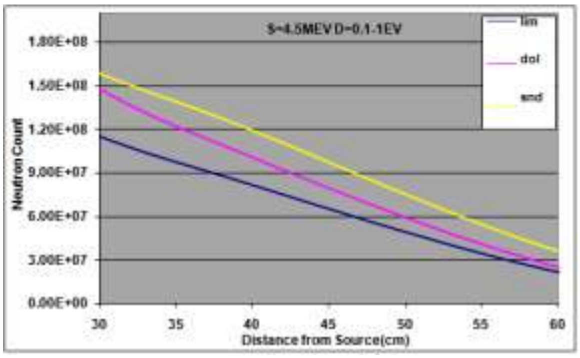

Fig. 7. Counted neutron by detectors in various effective distances between source and detectors in various energy span in calcite, dolomite and sandstone environments

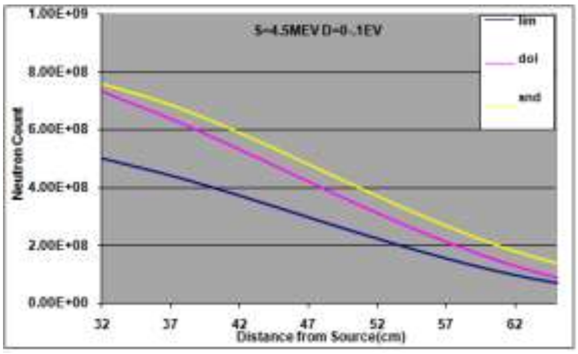

Fig. 8. Counted neutron by detectors in various effective distances between source and detectors in various energy span in calcite, dolomite and sandstone environments

When the source energy is in energy span of 100Kev-2Mev, the results of simulating relative to counting the neutrons with moderate energy, epithermal and thermal in effective distances from the source in each energy span is also like to previous figs. in the same section, that due to being repeated, it is avoided of mentioning them. The cause of the curves is also similar to the previous states in the same section.

when the source energy is in moderate energy span (1ev-100kev), the related results to counting neutrons with epithermal and thermal energy in effective distances from the source in each energy span and when the source energy is in epithermal energy span (0.1ev-1ev), the related results to counting thermal neutrons in effective distance from the source is examined in this energy span, It is proved that the results of these energy spans are also similar to previous states in the same section. The cause of the curves is also similar to the previous states in the same section.

An important result from explanation in parts A and B can be concluded that the behavior of neutron well log in various environments is dependent on detected neutrons energy and the distance of the detectors from the source. Another very important point obtained in this section from the simulating by MCNP4C code for designing neutron well log, is the effect of neutron source energy and the effect of detected neutrons energy and distance dependency of the detector from the source, to energy of the detected neutrons and source neutrons, that have considerable effect on behavior of each curve alone, and on the curves behavior to each other.

Both of explained factors in parts A and B about the near and far detectors counting are effective in neutron well log. Both of mentioned factors are adaptive to neutron counting in near and far detectors. Both cases of A and B that is simulated in this study, is simulated for the conditions that the matrix type is fixed and the formation porosity and as a result the fluid content of formation changes, to examine the behavior of neutron well log calibration curve which is the first and the most principal curve in neutron well log. That simulation results were like the obtained results in this study which due to being repeated, it is avoided of mentioning it.

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