A Simulation Study on the Sensitivity of Neutron Logging Sonde Response by Formation Thickness

Ill-hyuk Han, Geehyun Kim*
Department of Nuclear Engineering, Seoul National University, 1, Gwanak-ro, Gwanak-gu, Seoul, Korea
gk.rs@snu.ac.kr

1. Introduction

Well logging is the technique how Sonde detector moved into borehole to configure geological stratum. Since 1927, a number of well logging measurement methodologies have been invented: electrical, acoustic, radioactive, etc [1]. Neutron-neutron logging, one of radioactivity logging methods, is used to figure out rock porosity through the neutron scattering reaction. Neutrons from source in Sonde would be detected in Sonde detector after scattered by surrounding rock. However, the scattering reaction occurs in the two-surrounding rock at the boundary of layer. For this reason, neutron logging is difficult to figure out porosity on the boundary of layers. This paper covered sensitivity of neutron logging by thickness of stratum through Monte Carlo simulation and analyze neutron Sonde response curve with the number of neutron reaction in detector by energy.

2. Methods

2.1. Monte Carlo Simulation

Neutron Sonde was simulated with Monte Carlo code, MCNP6.2. Neutron source and detectors are AmBe source and CLYC-6. The stratum consists of bulk rock (shale, granite) and thin rock layer (sandstone) in the middle. Thin rock layers thickness are 10 cm, 50 cm, and 100 cm. Generally, water is added when digging a borehole to cooling the system. It makes mud, mixed with water and surrounding rock, fill the space between Sonde and stratum. To simplify the problem, it was assumed that the mud density was constant regardless of rock type, and the ratio of water to rock composing the mud was determined by mud density. Compositions of rocks refer to PNNL data [2]. In the stratum, Sonde passes through a thin rock layer from top to bottom. Sonde position is defined by position of Sonde bottom surface and position 0 cm refers the top surface of thin rock layer.

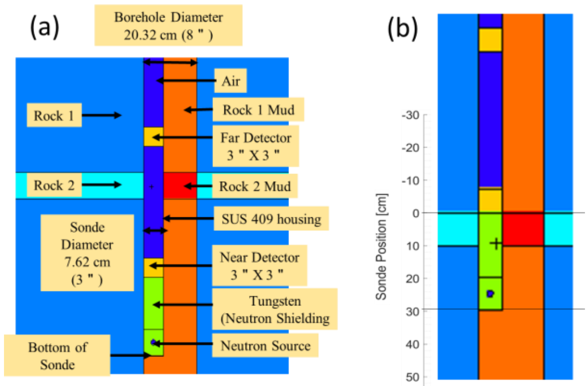

Fig. 1. (a) Simulated neutron logging system geometry with MCNP6.2 when thin rock layer thickness is 10 cm. (b) Example case of Sonde position at 30 cm.

2.2. The Number of Neutron Reaction by Energy

Neutron reactions in CLYC-6, $^{6}Li(n, \alpha)^{3}H$, $^{35}Cl(n, p)^{35}S$ and $^{35}Cl(n, \alpha)^{32}P$, are calculated with neutron flux and reaction cross section by energy [3]. Neutron energy is classified into three sections: thermal (< 0.5 eV), epithermal (0.5 eV ~ 1 MeV) and fast (1 MeV <). Below picture is an example for near detector's energy distribution of neutron reaction signal with three sections in stratum of single rock. Generally, neutron Sonde collect total neutron count signals from far detector and near detector to configure porosity of rock. However, energy distribution of neutron reaction only in near detector could also find out porosity of rock so that it would be used in this study.

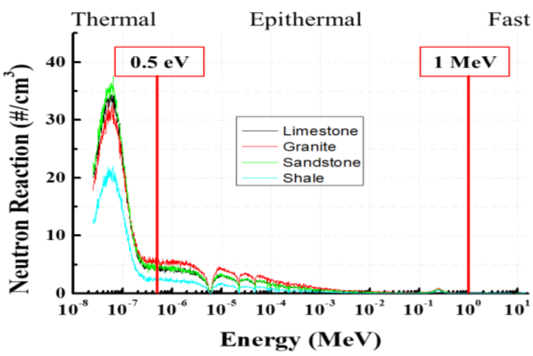

Fig. 2. Example for near detector's energy distribution of neutron reaction by rock type with three sections in stratum of single rock.

3. Results

3.1. Neutron Sonde Response

Figure 3 shows that neutron Sonde response by thin rock layer thickness. Neutron reaction means neutron counts of unit volume in the full energy range in near detector. Dash lines represent reference signal of neutron Sonde of rock. Magenta and blue mean bulk rock type (shale, granite) and thin rock type (sandstone), respectively. Neutron Sonde signal saturated at blue dash lines with 100 cm thin layer, regardless of whether rocks are sedimentary or igneous.

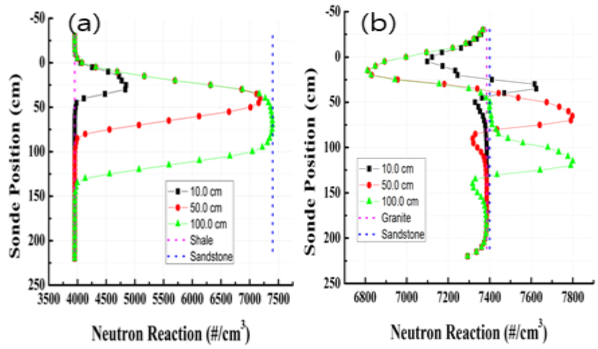

Fig. 3. Neutron Sonde response in (a) Shale-Sandstone stratum and (b) Granite-Sandstone stratum.

3.2. Neutron Reaction Energy Distribution

In this section, neutron Sonde responses are analyzed from energy distribution of neutron reaction with 100 cm thin rock layer, where signal of neutron Sonde is saturated, by Sonde position. Figure 4 show that energy distribution of neutron reaction at three positions. Position -30 cm and 70 cm whose Sonde neutron signals are flat, refer to where Sonde neutron source and detector are in bulk and thin rock. Position 30 cm and 120 cm whose Sonde neutron signals are changing, refers to where Sonde neutron source and detector are at different rock each other.

In Figure 4. (a) and (b), both of thermal and epithermal neutron counts at position 120 cm are settled in the middle of -30 cm, shale signal, and 70 cm, sandstone signal. For this reason, there is no fluctuation in neutron Sonde response. However, in Figure 4. (c) and (d), thermal neutron counts at position 30 cm are same with granite (-30 cm) while epithermal ones are same with sandstone (70 cm). Because neutrons occur as fast neutron at source, epithermal and thermal neutron counts are equal to rock type around source and detector. Due to this, there are fluctuation in granite-sandstone stratum.

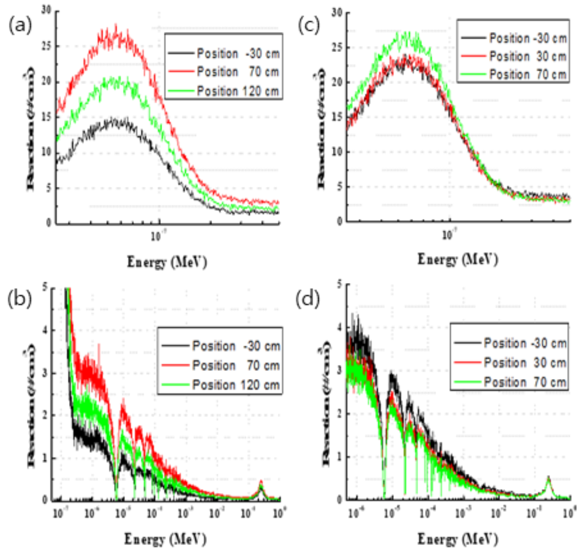

Fig. 4. Energy distribution of neutron reaction in (a) thermal, (b) epithermal section of shale-sandstone and (c) thermal, (d) epithermal section of granite-sandstone stratum by position.

4. Conclusions

Neutron-neutron logging could figure out not a point of stratum but range of it. The neutron Sonde is detectable about over 100 cm thickness of thin rock layer regardless of rock composition. With under 100 cm thickness layer, neutron Sonde response curve does not reach thin layer rock's own neutron counts. The shape of neutron Sonde response is different depending on the type of rock because thermal and epithermal neutron counts show different trend each other. Thermal neutron counts are affected by the rock near the detector, while epithermal neutron counts do near the source.

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Ministry of Education (NRF-2018R1D1A1A02048400) and Korea Environment Industry & Technology Institute (KEITI) through Subsurface Environment Management (SEM) Project, funded by Korea Ministry of Environment (MOE) (2018002440004).

REFERENCES

[1] Ellis, D. V., & Singer, J. M., Well logging for earth scientists (Vol. 692), Dordrecht: Springer, 2007, pp.1-5.
[2] McConn, Ronald J., et al. Compendium of material composition data for radiation transport modeling. No. PNNL-15870 Rev. 1. Pacific Northwest National Lab.(PNNL), Richland, WA (United States), 2011.
[3] Giaz, A., et al. "The CLYC-6 and CLYC-7 response to γ-rays, fast and thermal neutrons." Nuclear Instruments and Methods in Physics Research Section A: Accelerators,

Spectrometers, Detectors and Associated Equipment 810 (2016): 132-139.