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

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INTRODUCTION

➢ Neutron Logging Sonde

- The method for configuring porosity or rock type of stratum
- Consists of two neutron detectors (CLYC-6) and one neutron source (AmBe)

➢ Rock Type

- Sedimentary rocks : Limestone, Sandstone
- Igneous rocks : Granite, Basalt, Diorite, Gabbro
- Shale : Sedimentary rock especially including lots of water (neutron absorber)

➢ CLYC-6 Scintillator (Cs_2LiYCl_6:Ce)

- Neutron detection with PSD technique (Pulse Shape Discrimination)
- Neutron Reaction
  - ✓ $^6Li(n, \alpha)^3H$: ~ 940 barns
  - ✓ $^{35}Cl(n, \alpha)^{32}P$ / $^{35}Cl(n, p)^{35}S$: 100 – 300 mbarns

METHODS

➢ Monte Carlo Simulation Geometry (MCNP6.2)

- Thickness of thin rock layer : From 10 cm to 100 cm with 10 cm interval
- Sonde detector position : From +25 cm to -225 cm with 5 cm interval
  - ✓ Sonde position defined as position of sonde bottom surface

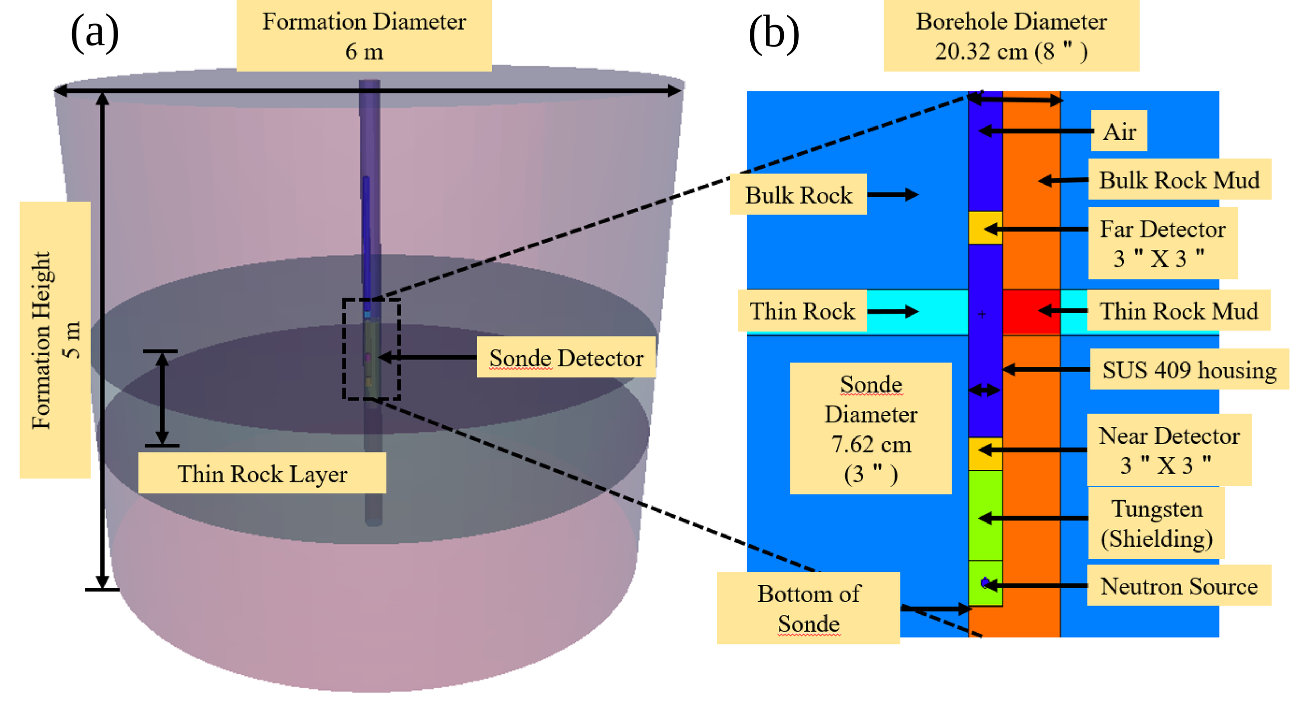

Fig. 1 MCNP6.2 simulation geometry
(a) Formation composition (b) Sonde detector composition

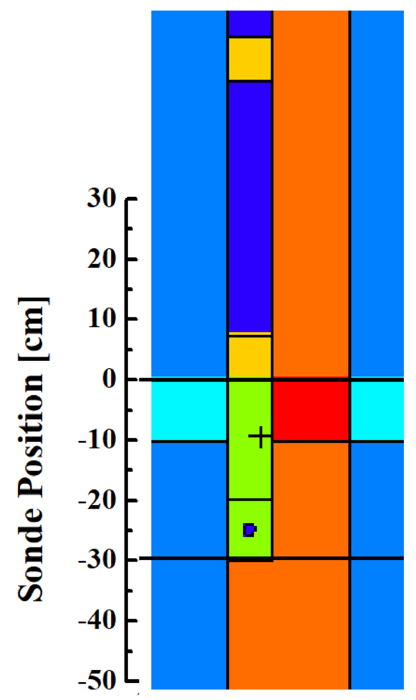

Fig. 2 Case of sonde position at -30 cm

➢ CLYC-6 Neutron Energy Sensitivity

- Neutron Energy
  - ✓ Thermal : < 0.5 eV
  - ✓ Epithermal : 0.5 eV – 1 MeV
  - ✓ Fast : > 1 MeV
- Rock Type
  - ✓ Higher counts of thermal neutron reactions in sedimentary rock
  - ✓ Higher counts of epithermal & fast neutron reactions in igneous rock

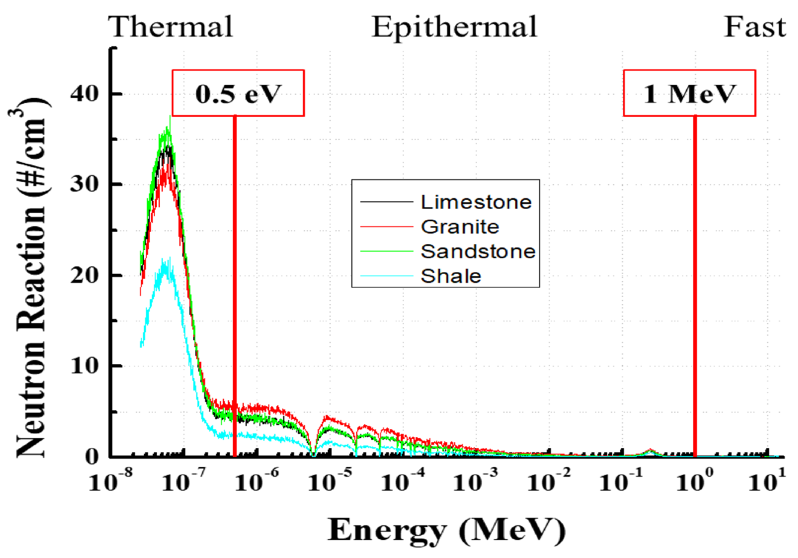

Fig. 3 Near detector's energy distribution of neutron reaction by rock type in single rock formation

RESULTS AND DISCUSSIONS

➢ Neutron Sonde Detector Sensitivity of Thin Rock Layer Thickness

- Limestone-Sandstone Case
  - ✓ Similar rock type formation
  - ✓ Both are sedimentary rocks
- Granite-Sandstone Case
  - ✓ Different rock type formation
  - ✓ They are igneous rock and sedimentary rock, respectively
- Shale-Sandstone Case
  - ✓ Formation including Shale
  - ✓ Shale is effective neutron absorber
- Saturation of neutron sonde response at thin rock reference signal (red dash line) when its thickness is above 100 cm

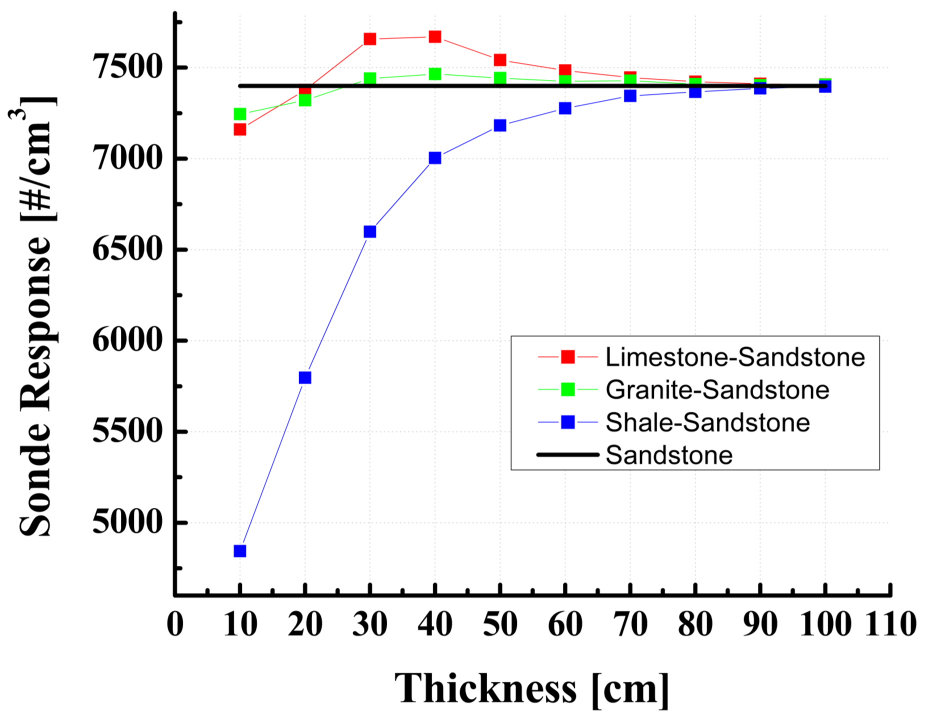

Fig. 4 Neutron sonde response of near detector by thickness in strata

➢ Fluctuation of Neutron Sonde Response Curve

- Two components in fluctuation of neutron sonde response curve
  - ✓ Thermal neutron region : Effects of rock type around neutron detector
  - ✓ Epithermal and fast neutron regions : Effects of rock type around neutron source

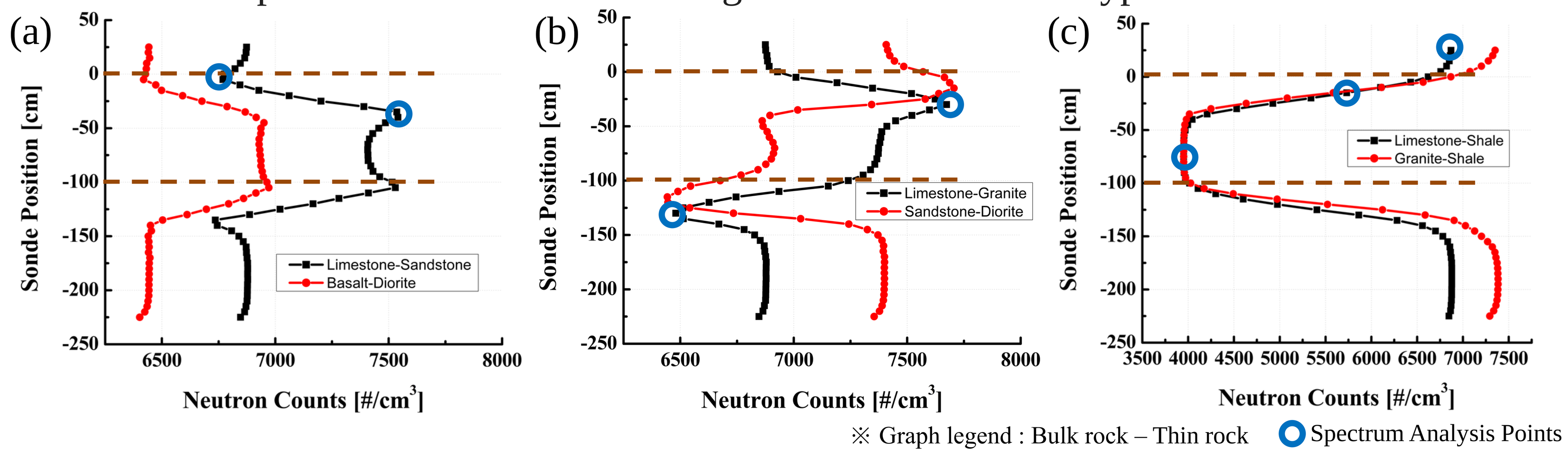

Fig. 5 Near detector response curve with 100 cm thin rock layer
(a) Similar rock type formation (b) Different rock type formation (c) Formation including Shale

(a) Similar Rock Type Formation

- Minor difference in epithermal and fast regions with two sedimentary rocks
- Sonde position at 0 cm : Neutron source near to Sandstone, neutron detector in Limestone
  - ✓ Thermal neutron region same as Limestone case
- Sonde position at -40 cm : Neutron source in Limestone, neutron detector in Sandstone
  - ✓ Thermal neutron region same as Sandstone case

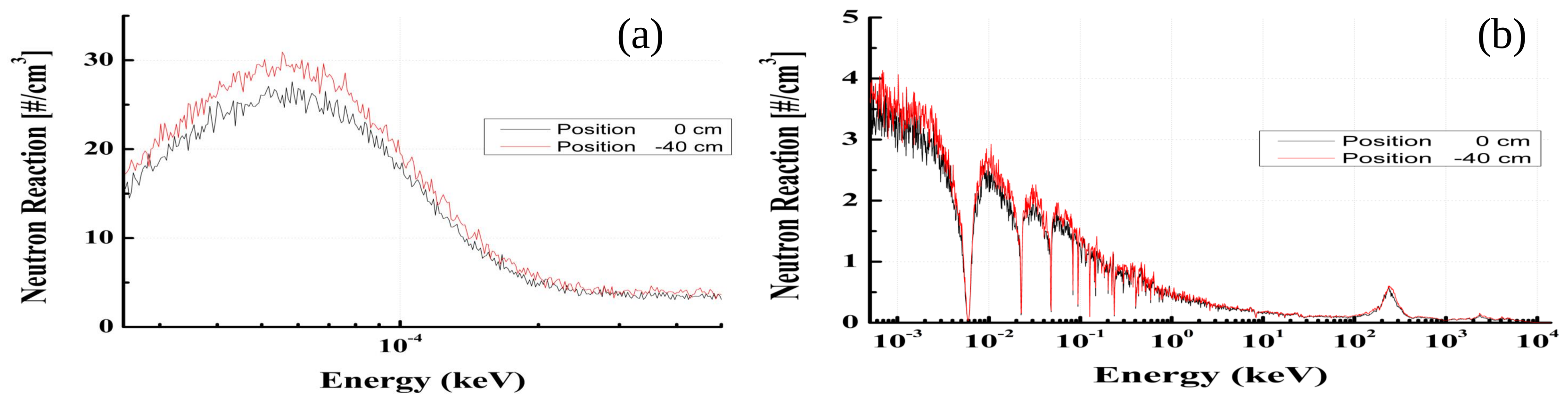

Fig. 6 Spectrum analysis of similar rock type formation (Limestone-Sandstone)
(a) Thermal neutron region (b) Epithermal & fast neutron regions

(b) Different Rock Type Formation

- Sonde position at -40 cm : Neutron source in Granite, neutron detector in Limestone
  - ✓ Thermal neutron region same as Limestone case
  - ✓ Epithermal and fast regions same as Granite case
- Sonde position at -130 cm : Neutron source in Limestone, neutron detector in Granite
  - ✓ Thermal neutron region same as Granite case
  - ✓ Epithermal and fast regions same as Limestone case

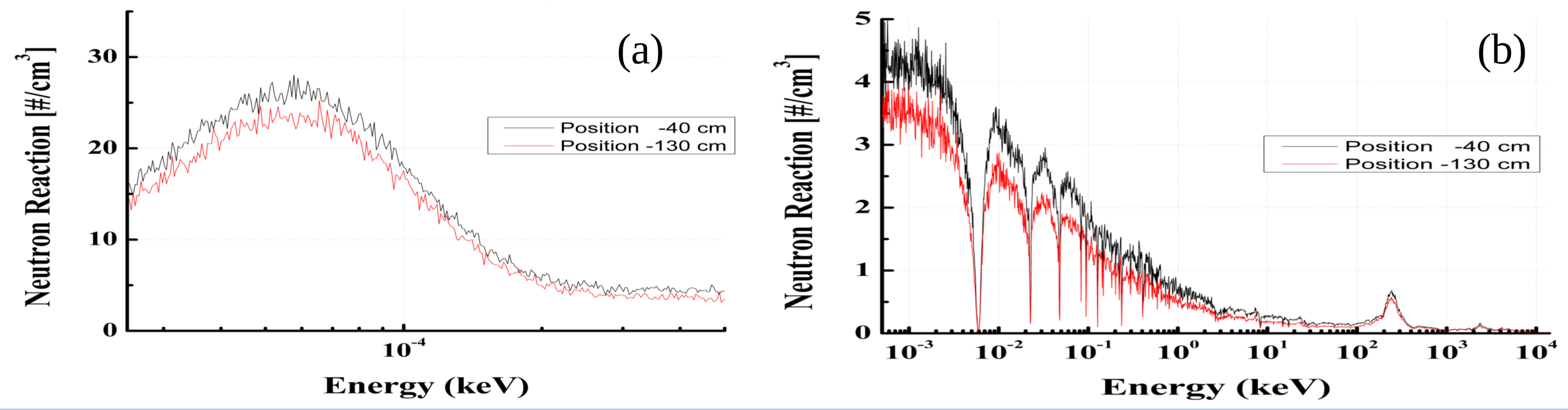

Fig. 7 Spectrum analysis of different rock type formation (Limestone-Granite)
(a) Thermal neutron region (b) Epithermal & fast neutron region

(c) Formation including Shale

- Due to Shale including lots of water, large difference of neutron counts in all regions, resulting in no fluctuations

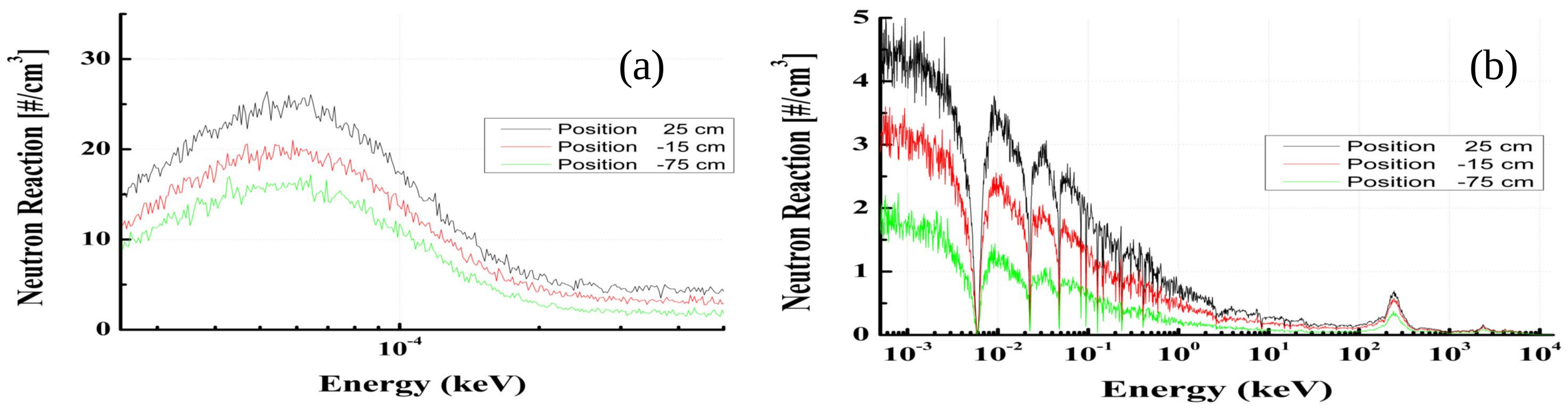

Fig. 8 Spectrum analysis of formation including Shale (Granite-Shale)
(a) Thermal neutron region (b) Epithermal & fast neutron region

CONCLUSIONS

- Stratum thickness sensitivity of neutron sonde is good enough to configure thin rock type when its thickness is above 100 cm.
- Neutron sonde response curves are fluctuated around boundary of rock due to difference of neutron affect in detector and source.
  - ✓ Thermal neutrons are affected by rock around neutron detector
  - ✓ Epithermal and fast neutrons are affected by rock around neutron source