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OPTIMIZATION OF MEASUREMENT SPEED FOR SPECTRAL GAMMA RAY AND CLAY MINERAL IDENTIFICATION

OPTIMASI KECEPATAN PENGUKURAN ALAT SPECTRAL GAMMA RAY DAN IDENTIFIKASI MINERAL LEMPUNG

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ABSTRAK

Log gamma ray adalah alat logging yang merekam tingkat radioaktif dari suatu batuan atau formasi yang diukur dalam satuan API unit (American Petroleum Institute). Alat log ini umumnya berfungsi untuk menentukan lapisan permeabel dan non-permeabel. Hal ini didasarkan atas fakta bahwa umumnya lapisan non-permeabel cenderung memiliki tingkat radioaktifitas yang tinggi dibandingkan dengan lapisan permeabel kecuali pada kasus batupasir felspatik. Selain itu, fungsi lain dari alat logging ini adalah menentukan jenis mineral menggunakan data perbandingan antara Thorium dan Potassium. Percobaan ini menggunakan alat Spectral Gamma Ray (SGR) yang ada di Laboratorium routine core Lemigas. Kualitas data hasil pengukuran log gamma ray sangat dipengaruhi oleh kecepatan dari conveyor belt. Berdasarkan hasil percobaan, kecepatan pengukuran sebesar 30 m/jam adalah kecepatan yang optimum untuk mendapatkan kualitas data yang baik dan efisiensi waktu dengan jumlah data 169 titik/meter. Hasil pengukuran SGR menghasilkan pembacaan kandungan Uranium, Thorium, dan Potassium. Kandungan Thorium (Th) dan potassium (K) dibandingkan dan dilakukan crossplot pada grafik Quirein, dimana grafik tersebut dimodifikasi kembali oleh Schlumberger pada tahun 1985. Dengan menggunakan crossplot ini mampu mengidentifikasi kehadiran mineral Chlorite, Montmorillonite, Kaolinite, Illite, Mixed layer clay, Feldspar, Mica, Glauconite, dll. Pada studi kasus yang dilakukan pada beberapa sumur (A1, A2, A3, A4, A5, A6 dan A7) menunjukkan bahwa hasil crossplot ini memiliki kesesuaian terhadap hasil pengukuran menggunakan XRD.

Kata Kunci: *log gamma ray, spectral gamma ray, kecepatan, identifikasi mineral.*

ABSTRACT

Gamma ray log is a logging tool to capture the radioactive level of a rock or formation measured in API units. This logging tool generally has a capability to differentiate between permeable and impermeable layers. Usually the impermeable layer tends to have higher radioactivity compared to the permeable one except for the feldspar bearing formation. In addition, another capability of this logging tool is to determine the kind of clay mineral, by using ratio data between Thorium and Potassium. This laboratory experiment used Spectral Gamma Ray (SGR) equipment at LEMIGAS Routine Core Laboratory. The quality of gamma ray log measurement is significantly affected by the speed of the conveyor belt. During the experiment, the measurement speed of 30 m/hour is the optimum speed to achieve good quality data and time efficiency with the data amount of 169 points/meter. The result of SGR measurement gives the reading on the content of Uranium, Thorium and Potassium. The Thorium and Potassium content are compared and plotted in Quirein graphic which was modified by Schlumberger in 1985. Using this crossplot, we can identify the presence of Chlorite, Montmorillonite, Kaolinite, Illite, mixed layer Feldspar, Mica, and Glauconite minerals. A case study conducted on Wells A1, A2, A3 and A4, indicated that the result of this crossplot were similar to the measurement using XRD.

Keywords: Gamma ray log, spectral gamma ray, speed, mineral identification.

I. INTRODUCTION

The radioactivity level being captured is the radioactive emission from Uranium, Thorium and Potassium (Krygowski, 2003., Asquith, 1982). There are two types of gamma ray log, i.e: 1) Simple Gamma Ray log or total Gamma Ray and 2) Spectral Gamma Ray. Simple Gamma Ray represents the total radiation from Uranium, Thorium, and Potassium, while Spectral Gamma Ray represents the radiation spectrum from Uranium, Thorium, and Potassium separately.

Gamma ray (GR) log is one of the logging tools which is always run in the upstream oil and gas industry. The principle of this tool is to capture all radioactive energy emitted by the rocks or reservoir layers. The radioactive emission in reservoir layers generally derives from three elements, which are Thorium (Th), Uranium (U) and Potassium (K) (Rider, 2002). Gamma ray measurement can be differentiated into two types i.e: 1) Total Gamma Ray which is also called Natural Gamma Ray (NGR) expressed in API (American Petroleum Institute) units and 2) Spectral Gamma Ray (SGR) expressed

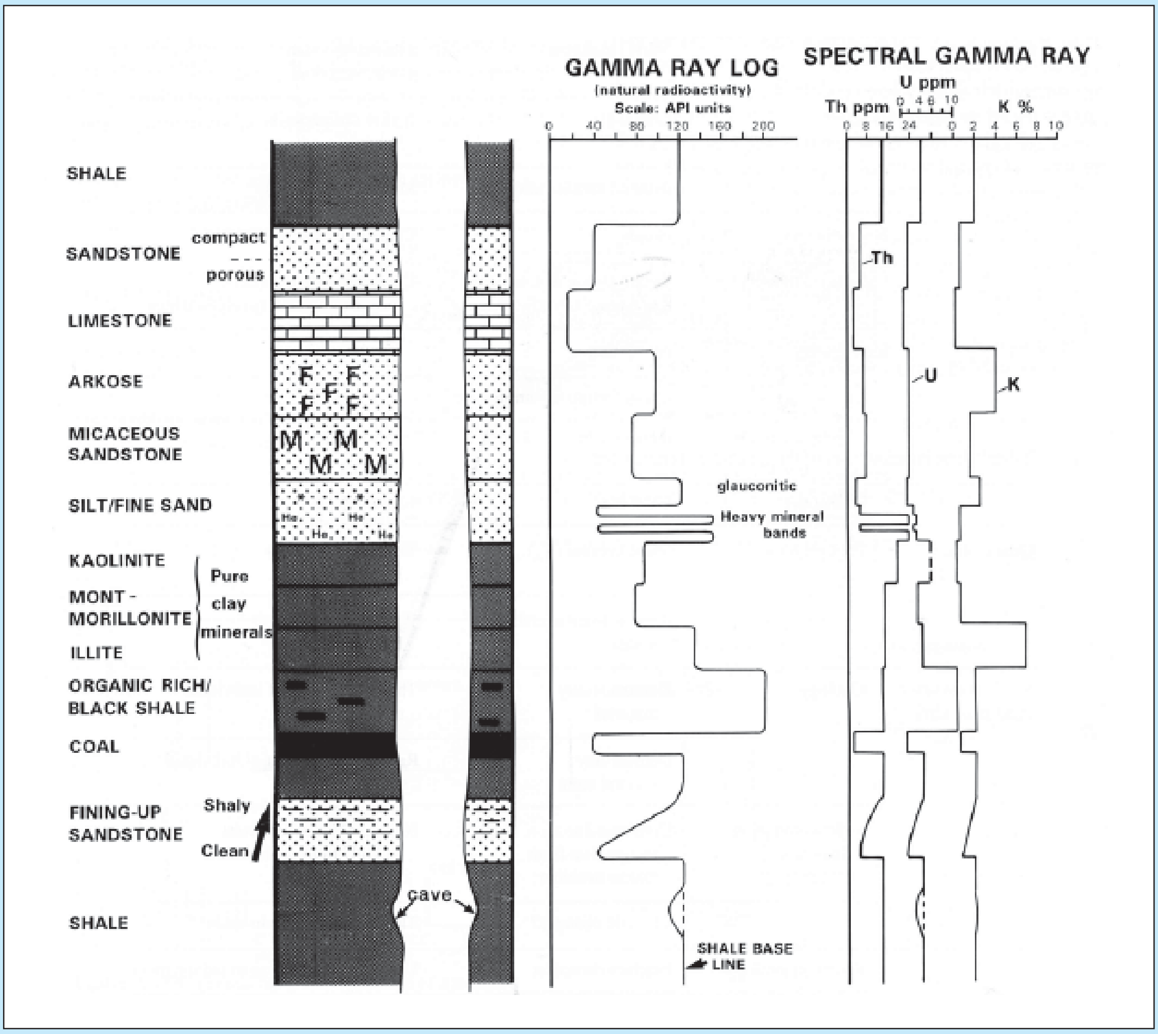

Figure 1
The difference between Total Gamma Ray/Natural Gamma Ray and Spectral Gamma Ray logs and their responses in several rock (Rider, 2002).

Table 1
The uses of Gamma Ray (A) and Spectral Gamma Ray log (B) (Rider, 2002)

(A)

	Discipline	Used for	Knowing
Quantitative	Petrophysics	Shale volume (*Vsh*)	gamma ray (max) gamma ray (min)
Qualitative	Geology	Shale (shaliness)	gamma ray (max) gamma ray (min)
		Lithology	typical radioactivity values
		Mineral identification	Mineral radioactivity
	Sedimentology	Facies	Clay/grain size relationship
	Sequence Stratigraphy	Parasequence & condensed sequence identification	Clay/grain size & organic matter/radioactivity relationships
	Stratigraphy	correlation	–
		Unconformity identification	–

(B)

	Discipline	Used for	Knowing
Quantitative	Petrophysics	Shale volume (V_{sh})	Th (max), Th (min) for pure shale
		Radioactive mineral volume	V_{sh} (Th), K (max), K (min) for shale
Semi-quantitative .and qualitative	Geology	Dominant clay material	Th, K, U content of individual clay minerals
		Detrital clay mineral suite	Radioactive content of individual clay minerals
	Sedimentology & Sequence Stratigraphy	Condensed section recognition from excess uranium	Normal U and Th content or Th/U ratio of shales
		Climatic changes?	Th/K ratio changes in shale
	Reservoir geology	Fracture detection	Uranium contribution to radioactivity
	Geochemistry	Marine source rock identification	Uranium content of organic matter

in ppm unit (part per million) and percent (%) (Serra, 1984).

The Total Gamma Ray values represent the summation of the total radiation of Thorium, Uranium, and Potassium elements. The Spectral Gamma Ray reading represents the measurement which is able to show seperately the percentage of each element (Figure 1).

In general, GR log is used in both qualitative and quantitative interpretation to calculate the shale volume, mineral identification, correlation, and the determination of permeable and impermeable layers (Table 1).

A laboratory scale use of this equipment at LEMIGAS Routine Core Laboratory identified both permeable and impermeable layers utilizing Total Gamma Ray.

Logging tools in most cases are easily affected by how the data was collected as well as environmental correction. Rider (2002) mentioned that in the process of data collection during gamma ray and spectral gamma ray data capture, the reading of the logging tool is very sensitive to the speed of tool movement. The measurement principle of the tool is based on capturing the radiation emitted by the elements in the form of radiation packages. Therefore it takes time for the receiver in the gamma ray tool to capture this radiation. Rider (2002) gives recommended speed for gamma ray measurement in the field.

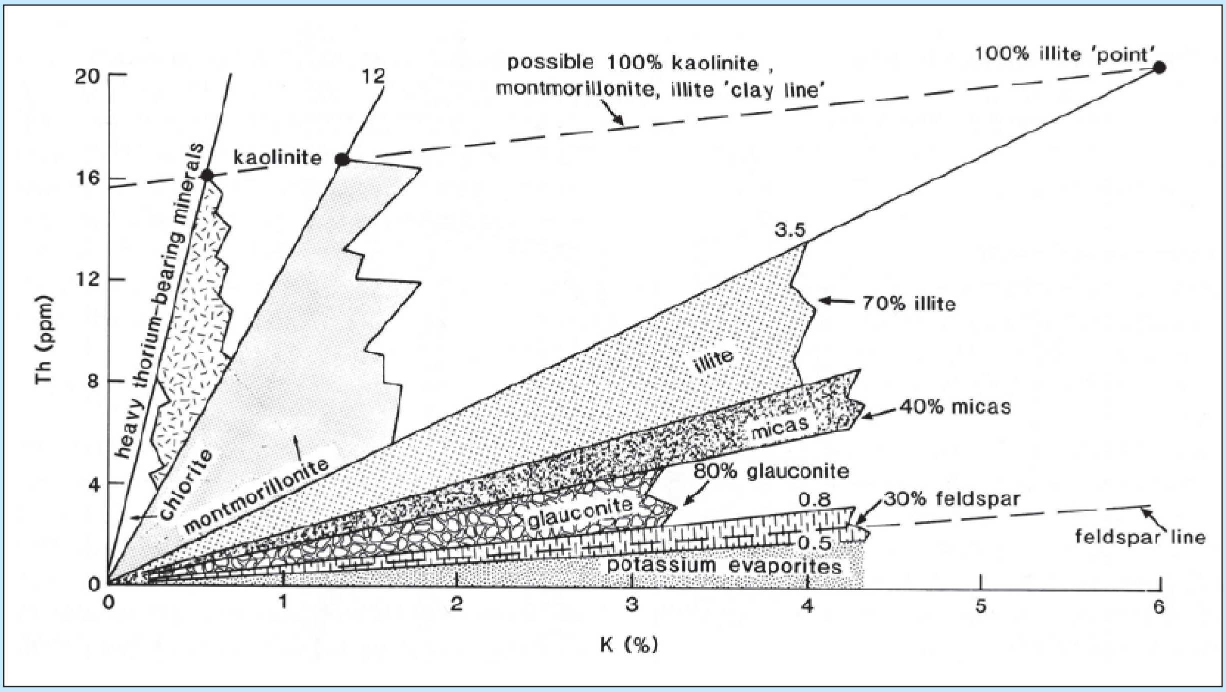

Figure 2
Crossplot of Thorium (Th) versus Potassium (K) for mineral identification (Quirren et.al., 1982).

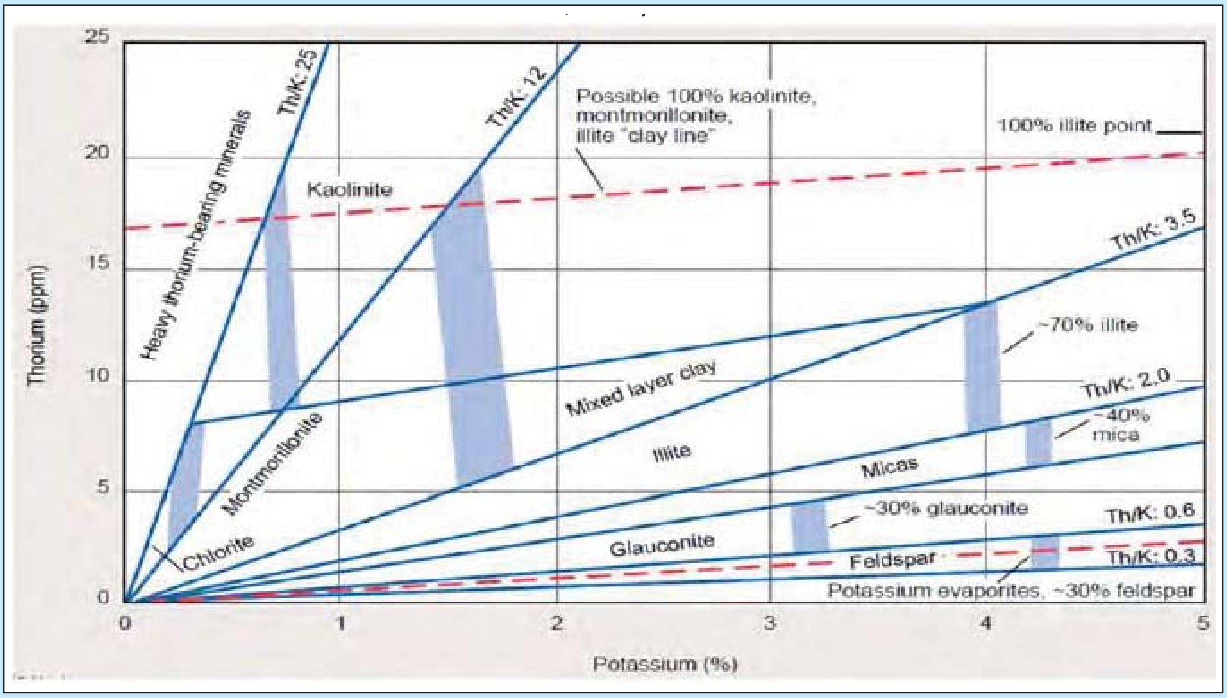

Figure 3
Crossplot of Thorium (Th) versus Potassium (K) for mineral identification (Schlumberger, 1985).

It was also mentioned that the sensitivity of measurement speed affects the amount of data recorded in the logging tool. The faster the tool moves, the smaller the amount of data being captured. The other impact is the discrepancy between the actual thickness of the layer compared to the thickness of the layer obtained from the measurement.

Quirren et al. (1982) generated *crossplot* of Thorium versus Potassium to conduct mineral identification (Figure 2). This crossplot can identify the presence of heavy thorium-bearing minerals, Kaolinite, Chlorite, Montmorillonite, Illite, Micas, Glauconite, Feldspar, and Potassium evaporite. Schlumberger (1985) conducted the development of this crossplot by adding one additional mineral type, mixed-layer clay (Figure 3).

Mohammadlou and Mork (2012) have done research on the uses of Spectral Gamma Ray log to identify clay mineral. In their research, they used crossplot of Thorium versus Potassium from the measurement to identify mineral type in the clay-rich zone. They compared the crossplot against the result from SEM-EDX analysis. The result indicates that the mineral identified using the crossplot method is similar to the one using the SEM-EDX method.

This paper discuss two topics i.e: 1). What is the optimum speed which can achieve good quality measurement while providing efficient operations time? 2). Optimizing the spectral data measurement for the purpose of mineral identification in a laboratory scale.

II. METHODOLOGY

This experiment primarily uses the Spectral Gamma Ray at LEMIGAS Routine Core Laboratory, Formation Evaluation Group of Exploitation Division (Figure 4). This tool consists of three main devices which are 1). Personal Computer, 2). Data processing/interpretation tool and 3). Spectral Gamma Ray sensor recorder.

The Spectral Gamma Ray tool consists of:

1. Square box in silver (the data processing/ interpretation tool of the Spectral Gamma Ray measurements)
2. Tube shape (the gamma ray radiation detector/ sensor equipment)
3. Pump to move the conveyor belt
4. Conveyor belt made from rubber and used to put moving sample above it.
5. Equipment to measure the speed of conveyor belt.

The method used to obtain the optimum and effective measurement speed is by comparing the amount of data, thickness and the time recording of the Spectral Gamma Ray measurement. In this experiment, four different speeds are used which are 15 m/hr, 30 m/hr, 60 m/hr, and 100 m/hr. Later on, we compare the amount of data being captured for each speed. The criteria of good, fair and bad were assigned after the data is applied for mineral interpretation.

The sample is 101 cm long and consists of two different lithologies; fine grain sandstone and clay (Figure 5). The boundary between the two lithologies lies at 71.5 cm and 98.5 cm and can be distinguished clearly from the difference in color. Based on the observation of sandstone in this sample, it can be differentiated into two parts which are SS-A (thickness = 71.5 cm) and SS-B (thickness = 2.5 cm), while the debris is categorized with code SLT (thickness = 27 cm).

The second method used in this experiment is specially designed for mineral identification.

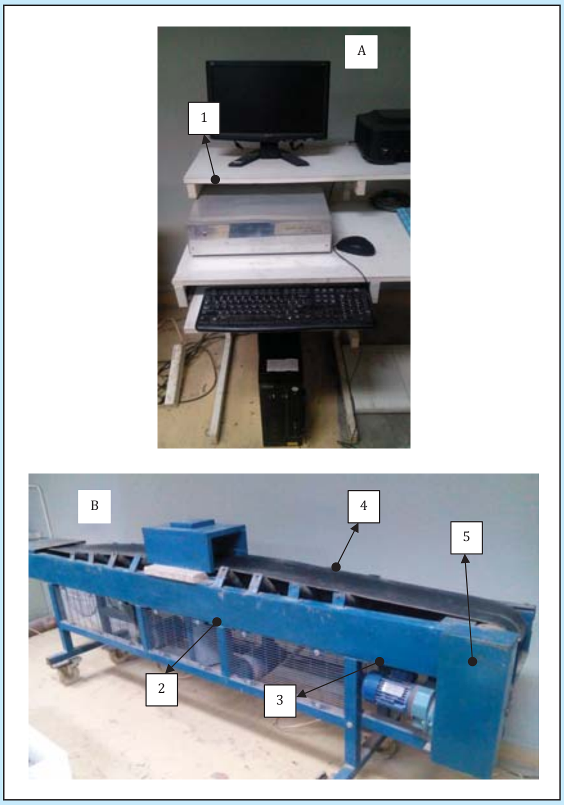

Figure 4
Spectral Gamma Ray Tool at LEMIGAS Routine Core Laboratory. A). Personal Computer and data processing/interpretation tool. B). Spectral Gamma Ray sensor recorder.

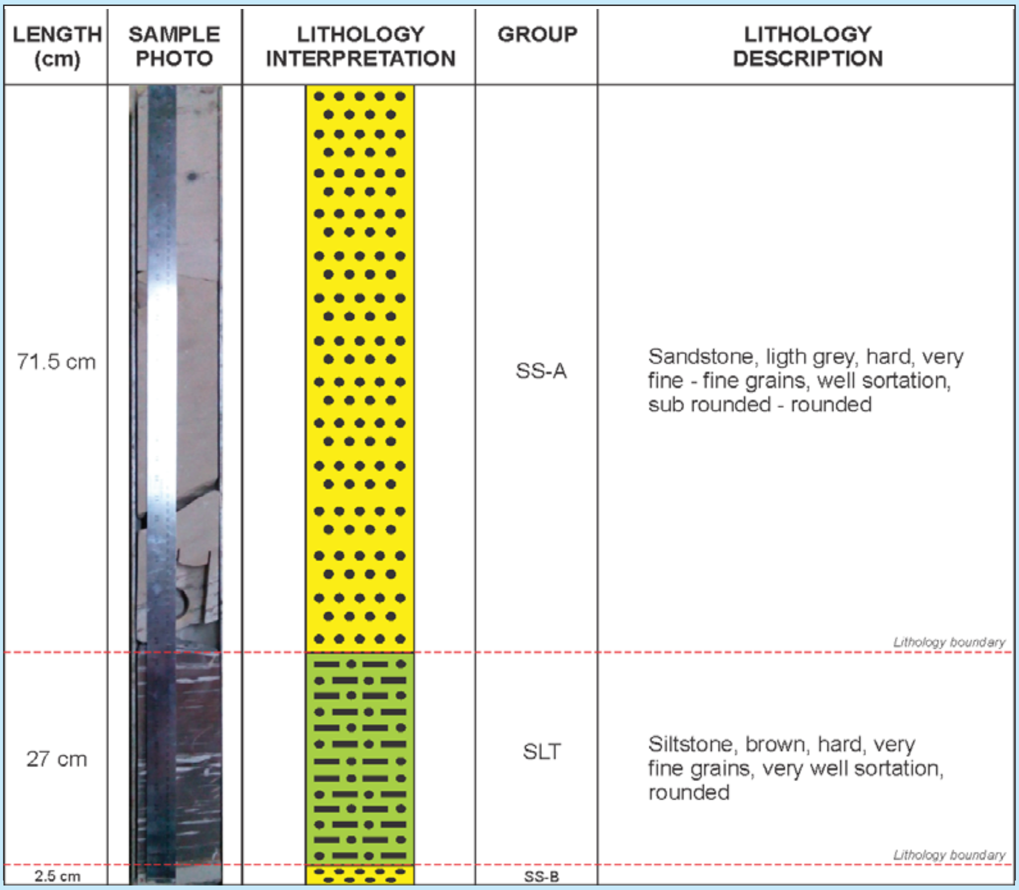

Figure 5
The core being use for the experiment to obtain the optimum and effective speed for A1.

Table 2
Speed versus the amount of data being captured

No	Speed (m/hr)	Amount of data (point/meter)	Siltstone thickness (cm)		The time required for each meter (minute)
			Measurement result	Observation result	
			Well A1		
1	20	1037	27	27	45 menit
2	30	169	27	27	30 menit
3	60	38	18	27	15 menit
4	100	18	18	27	6 menit

The method being used is comparing the result of Thorium versus Potassium cross-plot against XRD measurement. Xray powder defraction method was used for XRD analysis in this research (Poppe, 2002).

III. RESULTS AND DISCUSSION

A. Optimum Speed and Efficient Operation Time

The results of the experiment on optimum speed are presented in Table 2 and Figure 6. Table 3 and Figure 6 show that the slower the speed the more data is captured. In addition, the accuracy of thickness measurement is improved (thickness is equal to the measurement). Table 2 also shows that the efficient speed is at 30 m/hr. A speed of 30 m/hr indicates that more data is being captured. It also shows that the efficient speed is at 30 m/hr. At 20 m/hr speed the results shows more data being captured, however it generates a more complex profile picture. At the speed above 30 m/hr, too little data is captured and the profile picture generated becomes inaccurate, especially within the borderline between sandstone and claystone.

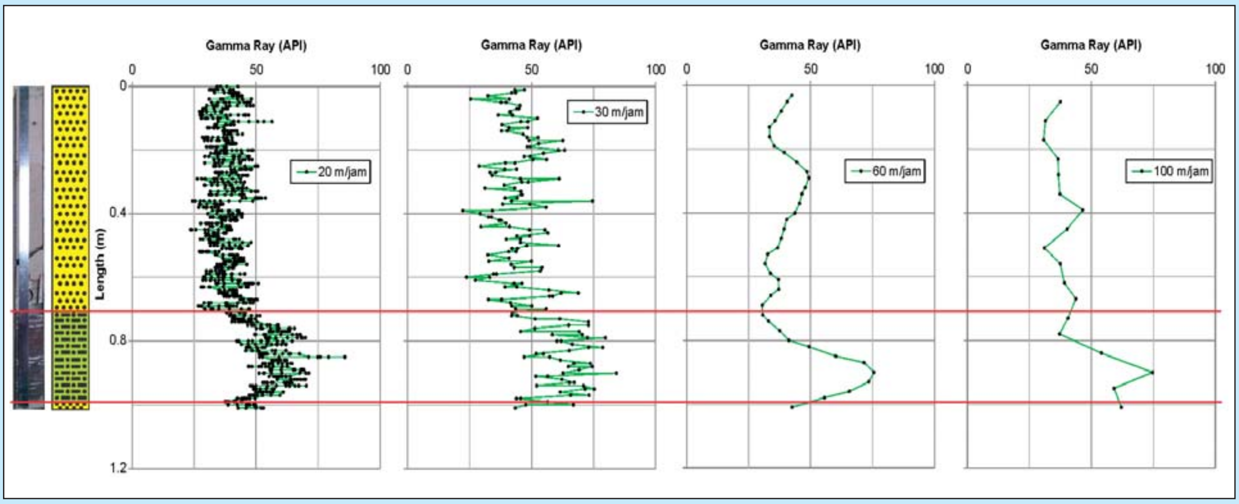

Figure 6
Layer speed versus thickness.

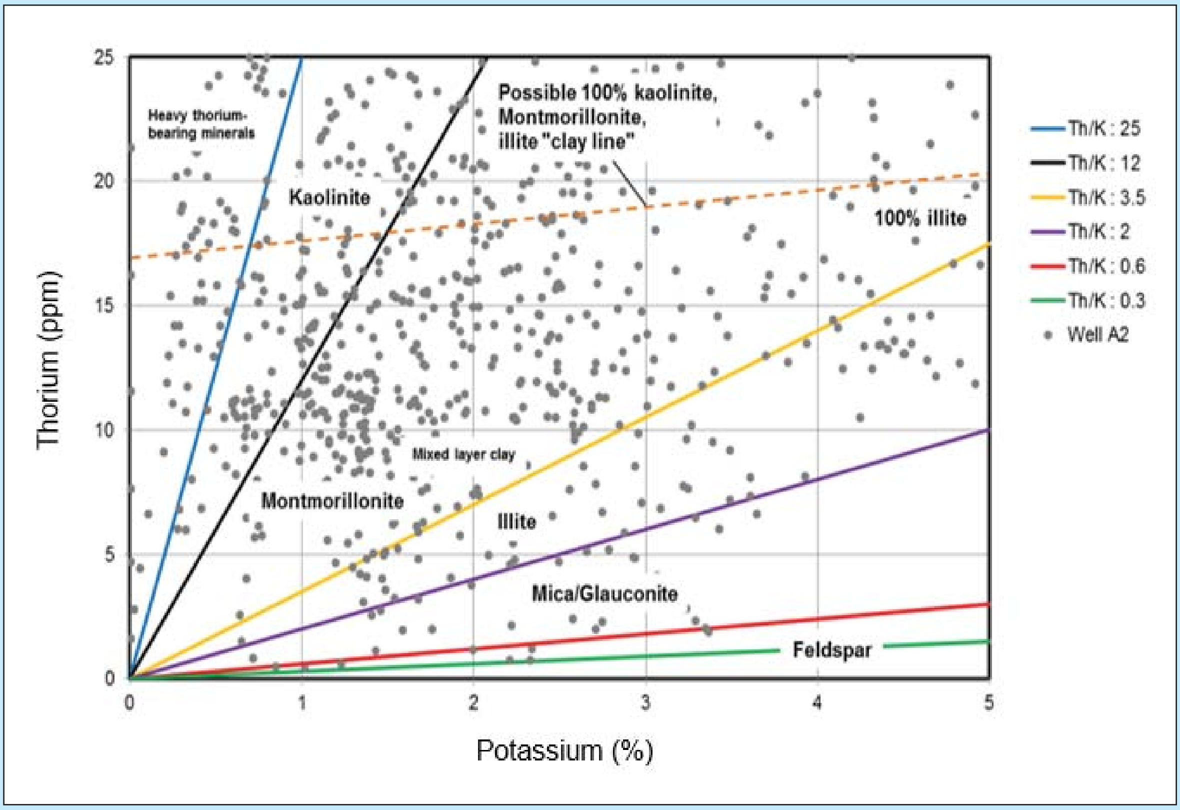

Figure 7
Crossplot of Thorium versus Potassium in Well A2.

B. Clay Mineral Identification

It has been mentioned previously that in this mineral identification experiment, 3 wells were used where each well has different character. As an example, in Well A2, the crossplot shows the possibility of the presence of feldspar, Mica/Galuconite, Illite, Montmorillonite/Smectite, Mixed layer, Kaolinite and Heavy Thorium bearing minerals

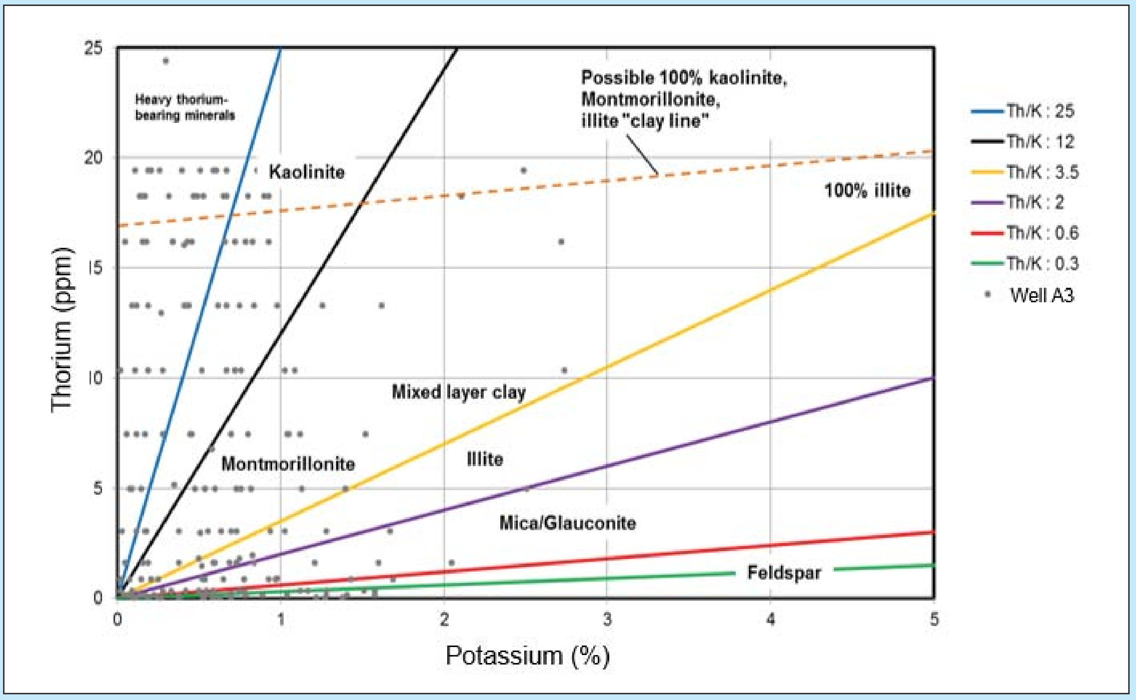

Figure 8
Crossplot of Thorium versus Potassium in Well A3.

Table 3
Analysis result of Well A2 XRD

NO	Depth (Meter)	Clay Minerals (%)				Carbonate Minerals (%)			Other minerals (%)				Total (%)		
		Smectite	Illite	Koalinite	Chlorite	Calcite	Dolmite	Siderite	Quartz	K-Feldspar	Plagioclasae	Pyrite	Clay	Carbonate	Other
1	886.31	-	3	8	-	-	-	-	85	1	3	-	11	0	89
2	886.65	-	3	12	-	-	-	-	83	-	2	-	15	0	85
3	887.62	-	6	20	-	-	-	-	68	2	4	-	26	0	74
4	888.40	-	6	20	-	tr	-	-	69	2	3	-	26	0	74
5	889.54	-	2	16	-	-	tr	1	78	-	3	-	18	1	81
6	890.40	-	2	6	-	-	2	-	89	-	1	-	8	2	90
7	89200	-	2	10	-	-	2	-	83	1	2	-	12	2	86
8	892.39	-	12	14	-	-	-	6	65	1	2	-	26	6	68
9	894.40	-	4	22	-	-	1	2	68	1	2	-	26	3	71
10	894.64	-	2	15	-	-	10	-	70	tr	2	1	17	10	73
11	962.4	-	5	23	-	-	2	3	57	-	10	-	28	5	67
12	964.00	-	5	17	-	-	3	3	66	1	5	-	22	6	72
13	965.85	-	4	20	-	-	5	3	64	1	3	-	24	8	68
14	966.23	-	10	10	-	-	-	7	70	-	3	-	20	7	73
15	967.43	-	12	18	-	0	1	7	57	-	5	-	30	8	62

Table 4
XRD analysis of Well A3

No	Depth (Meter)	Clay Minerals (%)				Carbonate Minerals (%)			Other Minerals (%)				Total (%)		
		Smectite	Illite	Kaolinite	Chlorite	Clacite	Dolomite	Siderite	Quartz	K-Feldspar	Plagioclase	Pyrite	Clay	Carbonate	Other
1	1181.69	-	8	10	-	-	-	-	91	1	-	-	18	0	82
2	1182.25	-	4	6	-	-	-	-	90	tr	-	-	10	0	90
3	1182.61	-	2	4	-	-	-	-	94	-	-	-	6	0	94
4	1182.92	-		5	-	-	-	-	91	1	-	-	8	0	92
5	1183.15	-	5	8	-	-	-	-	86	1	-	-	13	0	87
6	1183.47	-	5	9	-	tr	-	-	85	1	tr	-	14	0	86
7	1183.87	-	3	6	-	tr	tr	tr	89	2	-	-	9	0	91
8	1184.06	-	4	5	-	tr	tr	tr	87	4	tr	-	9	0	91
9	1184.48	-	5	10	-	tr	tr	-	83	2	-	tr	15	0	85
10	1184.70	-	4	7	-	tr	1	tr	86	2	tr	tr	11	1	88
11	1184.92	-	3	8	-	-	tr	tr	85	4	-	tr	11	0	89
12	1185.09	-	5	10	-	tr	tr	1	80	4	-	-	15	1	84
13	1185.40	-	6	12	-	1	1	1	74	5	-	-	18	3	79
14	1185.66	-	4	18	-	1	1	-	63	8	-	5	22	2	76

(Figure 7). The presence of those minerals is also seen in the XRD responses such as Illite, Kaolinite and K-Feldspar (Table 3). From the two analyses, there are similarities in the amount of data in the crossplot and the percentage of minerals from the XRD measurement of those three minerals.

The crossplot shows the possibility for the presence of Feldspar, Mica/Glauconite, Illite, Montmorillonite/Smectite, Kaolinite, Chlorite and Heavy Thorium bearing minerals. This figure shows the amount of data over Feldspar, Mica/Glauconite and Illite area, which is small. On the other hand, the area over Kaolinite and Montmorillonite/Smectite minerals has much more data on the plot.

XRD analysis results on several samples of core plugs are similar, showing the presence of Illiite, Kaolinite, and K-Feldspar minerals (Table 4). XRD analysis also shows higher Kaolinite content for both K-feldspar and Illite. However, Illite has a higher percentage compared to K-feldspar. This is similar to the amount of plotted Spectral Gamma Ray data.

Third, Well A4 (Figure 9), has a crossplot which shows the presence of Feldspar, Mica/Glauconite, Illite, Montmorillonite/Smectite, Kaolinite, and Heavy thorium bearing minerals. Montmorillonite/Smectite, Illite, K-feldspar, Kaolinite, and Chlorite minerals are also detected using XRD analysis (Table 5) except for Mica/Glauconite minerals.

The comparison of mineral analyses in the above wells shows quite good results by having a similar outcome from Spectral Gamma Ray analysis compared to that of XRD. The well detected minerals in these two methods are Illite, Kaolinite, and Feldspar. However, Montmorillonite/Smectite and Chlorite minerals were well detected using these two methods only in Well A3. The minerals that rarely show up in XRD analysis are Mica/Glauconite and Montmorillonite/Smectite. There are two possible interpretations i.e: 1). Montmorillonite/Smectite detected by Spectral Gamma Ray is actually from drilling mud. 2). Montmorillonite/Smectite is not detected in XRD analysis while Mica is difficult to be detected by XRD since it has similar response as Illite mineral. Glauconite mineral is also difficult to detect by XRD but can be easily detected using petrography method.

IV. CONCLUSION

Optimum speed is achieved at 30 m/hr. Lower speed captures a lot of data but gives a complex

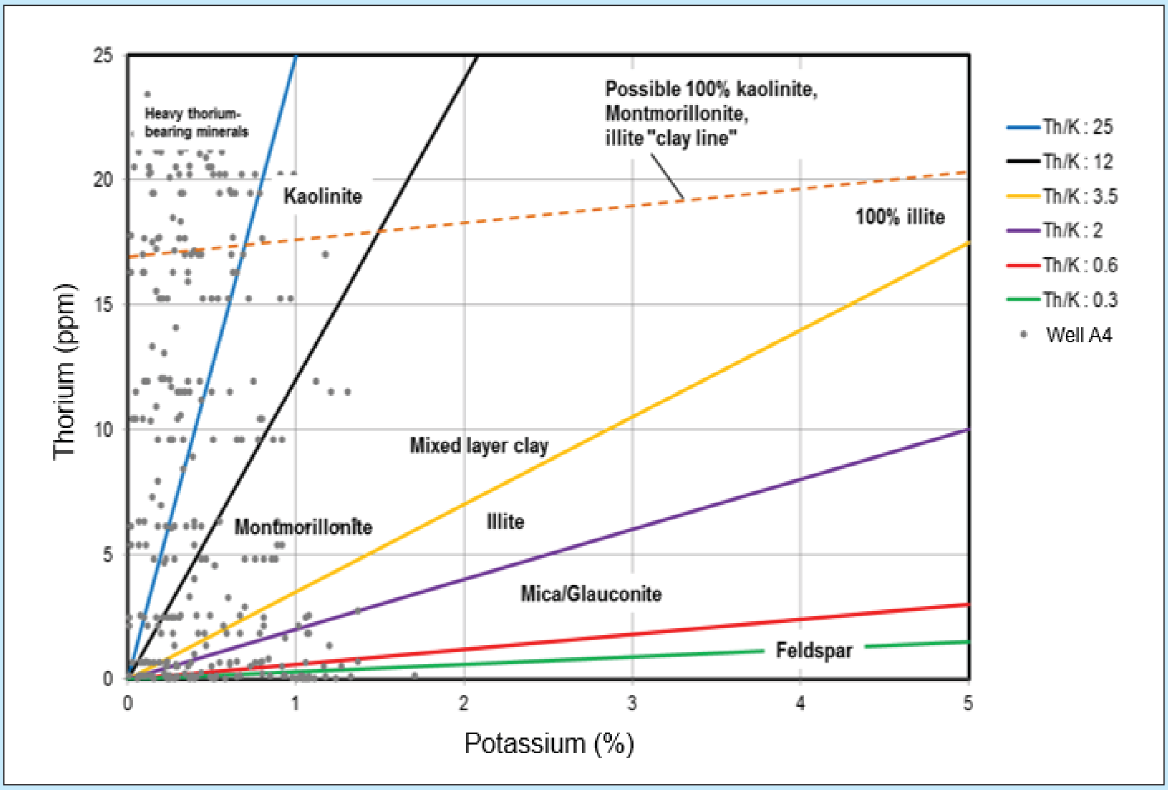

Figure 9
Crossplot of Thorium versus Potassium in Well A4.

Table 5
XRD analysis of Well A4

No	Depth (Meter)	Clay Minerals (%)				Carbonate Minerals (%)			Other Minerals (%)				Zeolite (%)		Total (%)		
		Smectite	Illite	kaolinite	Chlorite	Calcite	Dolomite	Siderite	Quartz	K-Feldspar	Plagioclase	Pyrite	Lamonite	Clinoptilolite	Clya	Carbonate	Other
1	1032.67	-	2	30	-	tr	-	1	67	-	-	-	-	-	32	1	67
2	1034.09	-	3	20	8	-	-	-	69	-	-	-	-	-	31	0	69
3	1035.75	-	4	28	14	-	-	-	54	-	-	-	-	-	46	0	54
4	1036.55	-	1	15	14	tr	-	2	68	-	-	-	-	-	30	2	68
5	1038.22	-	-	4	-	-	-	-	96	-	-	-	-	-	4	0	96
6	1039.07	-	-	3	-	-	-	-	97	-	-	-	-	-	3	0	97
7	1176.15	10	2	3	5	18	2	-	47	4	6	-	tr	3	20	20	60
8	1176.75	20	2	-	5	8	-	-	47	6	8	-	4	-	27	8	65
9	1177.84	30	6	-	10	-	-	-	30	10	10	tr	-	4	46	0	54
10	1178.36	30	3	-	8	-	3	-	40	5	7	-	-	4	41	3	56
11	1179.77	38	5	-	10	-	1	-	21	7	10	tr	-	8	53	1	46
12	1180.84	40	5	-	10	-	2	-	21	6	8	-	-	9	55	2	43

profile picture; while at a speed higher than 30 m/hr not enough data is being captured causing an inaccurate profile picture, especially across the boundary between sandstone and claystone.

SGR data can be used in crossplot to identify clay minerals. Quirren et al. (1982) generated a crossplot of Thorium versus Potassium to conduct mineral identification. It was proven that this crossplot was able to identify the presence of heavy thorium-bearing minerals, Kaolinite, Chlorite, Montmorillonite, Illite, Micas, Glauconite, Feldspar and Potassium evaporite.

XRD is one of the validation methods for SGR qualitative and quantitative analysis in initial identification of clay minerals. Comparison to XRD indicates similar results were obtained especially for Kaolinite, Feldspar, and Illite minerals.

There are several clay minerals (Montmorillonite/Smectite, Mica/Glauconite and Chlorite) captured in SGR but not in XRD. This can be caused by either not close enough sampling distance for the XRD analysis, or it requires complements from other methods for the identification such as Scanning Electron Microscope (SEM), SEM-EDX and petrografi.

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