

# **Integrated Lab Studies For Uranium Exploration in High Radioactive Formations\***

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## **Abstract**

With the shrinking sources of the fossil fuels, the lookout for alternate energy sources has attained new dimension. Nuclear energy is one such source, which can, to an extent ease the pressure on fossil fuels. Nuclear reactors need Uranium for fission reactions to generate energy.

The Krishna- Godavari basin has many wells drilled having high gamma ray values. The Raghavpuram shales have two distinct units - the high GR high resistivity and low GR low resistivity units. Of these, the high GR unit of Raghavpuram shales looks more interesting for uranium exploration. However, in the absence of NGS log in most of the wells, studies on the core samples of these wells in laboratory are the only option.

The samples from cores of K-G basin have been studied for Uranium content. NGS data has been acquired in the lab on claystone/sandstone/shale samples of conventional cores of Raghavpuram Shales, sedimentological studies have also been carried on representative core samples. Analysis of the acquired data in Raghavpuram shales give the distribution of Thorium, Potassium and Uranium concentration. Transforms have been generated between log gamma ray and core measured uranium in Raghavpuram shales. These transforms can then be used to estimate uranium concentration from log gamma ray in the respective field.

This paper explores the possibility of application of integrated studies for estimation of uranium concentration. The uranium concentration so estimated can then help in defining the exploration strategy for Uranium mining. One such method is In Situ

Leaching (ISL). ISL is a cost effective method but its success depends on the concentration of Uranium. Thus, integrated lab studies can help in deciding whether to employ ISL or not.

## **Introduction**

Natural radioactivity in the formation is a known phenomenon. The use of Natural gamma ray in the correlation of subsurface formation is not a new technique. The conventional gamma Ray log records the total natural gamma ray radiations. These radiations are emitted from three main types of source elements: K, Th and U (and their decay products). The gamma rays emitted by the three decay series have a number of discrete energies. The relative amplitudes of the three spectra will depend on the radioactive component present, enabling the quantitative evaluation of thorium, uranium and potassium.

Uranium occurs in nature as three isotopes: U234, U235 and U238. Of these, U238 is the most abundant. Uranium is transported mainly in solution owing to its solubility. Some uranium is also transported in suspension as heavy uranium bearing mineral. It is also transported with clays and organic matter in stable compound. For this study, the conventional cores of Krishna-Godavari Basin were selected based on high gamma ray response. Natural gamma ray spectroscopy (NGS) data has been acquired on claystone/ sandstone/ shales samples from cored intervals of Raghavpuram Shales, Konukollu Sandstones and Golapalli Formations in around 22 wells. Sedimentological studies have also been carried out on representative core samples. The NGS data has been analyzed to obtain Uranium concentration in the sediments.

## **Methodology**

The NGS laboratory study on the core samples was carried out using Multi-Detector facility. The detector assembly is encased in specially designed thick lead shield in order to minimize effect of environmental gamma ray activity. The first step of NGS study involves energy calibration of the detectors, using a multi-energy GR source. This provides calibration of detectors in terms of gamma ray energies versus the channel number under which gamma counts are recorded. The next sequence is the recording of background gamma ray spectrum for each of the detectors. Due to very weak background gamma ray activity, the spectrum is recorded for longer time duration.

The background corrected gamma ray counts within the respective energy peaks of K (1.46 MeV), U (1.76 MeV) and Th (2.62 MeV) are obtained from the spectra of standard rock sample and of the core samples. The elemental concentration of U is determined from the spectral data (gamma ray count rate) corresponding to signature energy peak of Uranium using following relation:

$$U \text{ (ppm)} = [SU * (R1.76 / W)]$$

Where, S = [Elemental Concentration \* (Sample weight / Gamma Ray count rate)] for standard rock sample. R = Gamma Ray count rate corresponding to signature peaks (1.76 MeV) for core samples. W = Weight of core sample (gm.) The Gamma Ray count rate is recorded as counts per minute per gram (cpmg).

### **Uranium Estimation with Natural Gamma Ray Spectroscopy**

In situ gamma ray measurement in borehole by wire line tool has been used extensively to identify uranium and other mineral resource. High gamma ray has been used as proxy for identification of strata rich in radioactive minerals. With the introduction of Natural Gamma Ray Spectrometry (NGS) tool, it is possible to differentiate the contribution of the gamma ray with respect to the spectral energies, which are characteristics of the elements. The uranium decay chain is shown in [Figure 1](#), which shows that uranium atom ultimately decays to stable lead isotope. In this chain, the daughter product Bismuth has a prominent peak at 1.76 MeV and can be used for quantitative estimation of uranium.

When secular equilibrium is reached in the decay chain, the activity of each daughter product is equal except lead. Disequilibrium can occur through out the chain if any process other than the radioactive decay loses one or more decay product. The daughter products because of difference in physical and chemical properties may exhibit preferential solubility in particular environment. Most of the core samples in the present study are from Raghavpuram Shale, Kanukollu Sandstone and Golapalli Sandstone, which range in geological age from late to early Cretaceous i.e. more than the threshold of million years and hence are in secular equilibrium. Thus, the uranium determination with Natural Gamma Ray Spectrometry is an acceptable and logical method for quantitative and qualitative purposes. However if the formation to be assessed are very young and prone to hydrogeological/leaching process than a suitable correction factor has to be applied. (Mihai et. al. 2005).

### **Analysis of Spectrometry data**

The Natural Gamma Ray data has been acquired on 175 conventional core samples in 22 wells of Kaza, Kaikalur, Lingala and Sanarudravarm fields located in Kaza-Kaikalur horst and Nimikiru, Dondapadu and Gajalapadu fields located in Gudivada Graben of Krishna- Godavari Basin. The wells under study ANG-1 and NDG-5 are in Tanaku horst and Bantumalli Graben respectively. The details of the core samples and measured concentration of uranium, thorium and potassium in each sample is compiled. The

sedimentological study on the representative core samples was carried out at Geology Laboratory, for identification of macro lithology and XRD and SEM for detailed clay typing for integration with NGS results. The core samples in the present study comprise of sandstone, silty claystone and shale.

### **Distribution of Uranium, Thorium and Potassium**

The distribution pattern of U, Th and K concentrations in core samples of Raghavpuram Shale in different wells is illustrated in [Figure 3](#). Uranium concentration generally lies in the range of 0.5 - 7.10 ppm. Most samples in Kaikalur shows higher uranium in upper range in wells Kaikalur-9, 4, 1 and Angalaru-1. Thorium concentration ranges between 3-30 ppm in majority of samples, though higher concentration of 30-98 ppm is found in cores of Kaikalur-4 and 9. Potassium concentration varies in range of 0.25-4.2%, however in cores of wells Kaikalur #9, 1, and Lingala 9 and 13 higher K content is present. It has been observed that presence of higher concentration of all the three radioactive elements i.e. U, Th and K in lower unit of wells Kaikalur -1, 4 and 9 and Lingala-9 and 13 is also reflected as high GR of 130-298 API on well logs against the corresponding cored intervals. The high gamma ray activity is due to high thorium concentration in the core samples and not because of uranium.

The distribution of uranium, thorium and potassium contents in 34 core samples is shown in [Figure 2](#). Potassium content is 0.5-5.5% in the well GJP-1, LNG-9, LNG-3, LNG-6, NDG-5 and KLR-11 however, the core samples of wells show higher content in the upper bracket. Average uranium content was in the 2 ppm whereas the samples from wells LNG-3 and 6 show higher content 3.8 ppm. The average thorium content in the samples of Kanukollu Sandstone is of the same order as the samples of Raghavpuram Shale and Golapalli Sandstone. The thorium content varies from 3-37 ppm. Few samples of wells KLR-1, LNG-3 and NDG-5 show higher content of thorium due to silty nature.

Thus from the above discussion it can be inferred that high gamma ray activity observed on well log responses in Raghavpuram Shale, Kanukollu Sandstone, Golapalli Sandstone and Gajulapadi Shale is contributed by high thorium content which is above the normal concentration in sedimentary rock and has peaked at 98.8 ppm. The uranium concentration analysis shows that most of the samples have low concentration. The threshold requirement for commercial exploitation by ISL method is 0.1%. The measured uranium concentrations are low; hence, the Raghavpuram Shale, Kanukollu Sandstone, Golapalli Sandstone and Gajulapadi Shale in wells of Kaza- Kaikalur horst, Gudivada Graben and Bantumali Graben are not prospective for uranium exploitation by ISL in K.G. Basin.

### **Spectrometry Application in Uranium Estimation Study**

Kaikalur Field: Total Gamma Ray (log) and core computed Gamma Ray is plotted for samples of Raghavpuram Shale in Kaikalur field. A correlation coefficient of 0.69 is achieved indicating the good coherency levels. The transform generated is:

$$\text{GRL} = 0.5863\text{GRCC} + 5.967875 \quad r = 0.69$$

This transform can be used to correct log recorded gamma ray for deviation due to bad borehole effects, effect of mud additives for a realistic gamma ray of the formation. The log-recorded gamma ray was also correlated with the measured uranium in core samples for wells in Kaikalur fields. (Figure 3) We find a good correlation between the two parameters with a correlation coefficient,  $r = 0.8854$  and plotted in Figure 3. The transform between GRL and core sample measured uranium is:

$$\text{GRL} = 25.357\text{U} + 13.5949 \quad r = 0.8854$$

This relation can be used to compute uranium content from gamma ray log against Raghavpuram Shale in Kaikalur field with high gamma ray and high resistivity feature mostly found in lower part of the formation.

Lingala Field: The transform for Raghavpuram Shale in wells of Lingala Field between GRlog and GRcore is:

$$\text{GRL} = 0.59\text{GRCC} + 72 \quad r = 0.74$$

The transform between GRL and core sample measured uranium plotted in Figure 4 is:

$$\text{GRL} = 11.78\text{U} + 85 \quad r = 0.53$$

The transform between gamma ray log (GRL) and gamma ray computed (GRCC) from weighted average of lab-measured concentrations of uranium, thorium and potassium for Kanukullu sandstone in Lingala Field which is characterized by alternate sand shale sequences and low radioactivity has shown higher intercept with good correlation coefficient of 0.64. The transform is:

$$\text{GRL} = 0.33\text{GRCC} + 55.49 \quad r = 0.64$$

Transform generated between cores measured uranium and GRL, plotted in [Figure 4](#) shows positive correlation coefficient, which is an indication of good coherency level. The transform is:

$$\text{GRL} = 11.24\text{U} + 55.3 \quad r = 0.53$$

High value of intercept is due the weighted average of thorium and potassium in GRL. Thus by correcting log gamma ray with the above transform correct value of gamma ray can be computed. This value can be used to compute uranium concentration in the corresponding formation to assess its uranium potential.

### **Conclusions**

The maximum concentration of uranium is less than 8 ppm in Raghavpuram shale in one of the Kaikukur well. The Average uranium is low to moderate as compared to Thorium concentration. The lab-determined uranium and log-measured gamma ray exhibits good trend and correlation for Raghavpuram Shale and Kanukollu Sandstone. One of the very important aspects in exploitation of Uranium is the understanding of lithology of the formation and porosity determination ([Figure 5](#) and [Figure 6](#)). Effective porosity is a vital input for the success of exploitation of uranium by ISL method. The study has integrated the XRD results for the ascertaining the nature of reservoir. The dominant clays are montmorillonite and kaolinite.

The generated transforms can be used to estimate uranium concentration from log measured gamma ray in respective fields. It is also clear from above study that high gamma ray formations may not necessarily be rich in uranium accumulation. This type of analysis will be very crucial in determining the uranium concentration in the old wells. Thus integrated lab studies are necessary before venturing out for uranium exploration.

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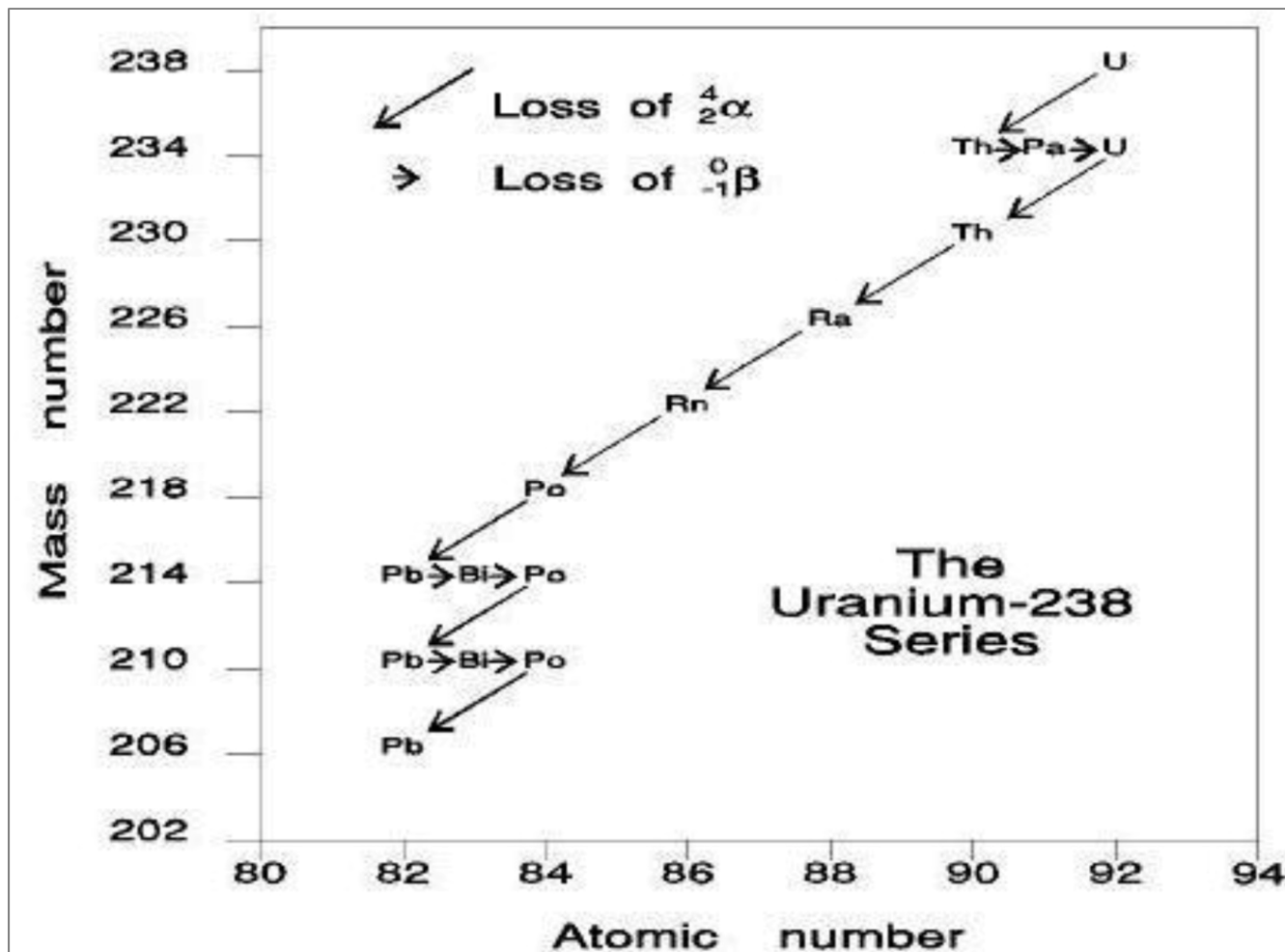


Figure 1. Decay of uranium series.



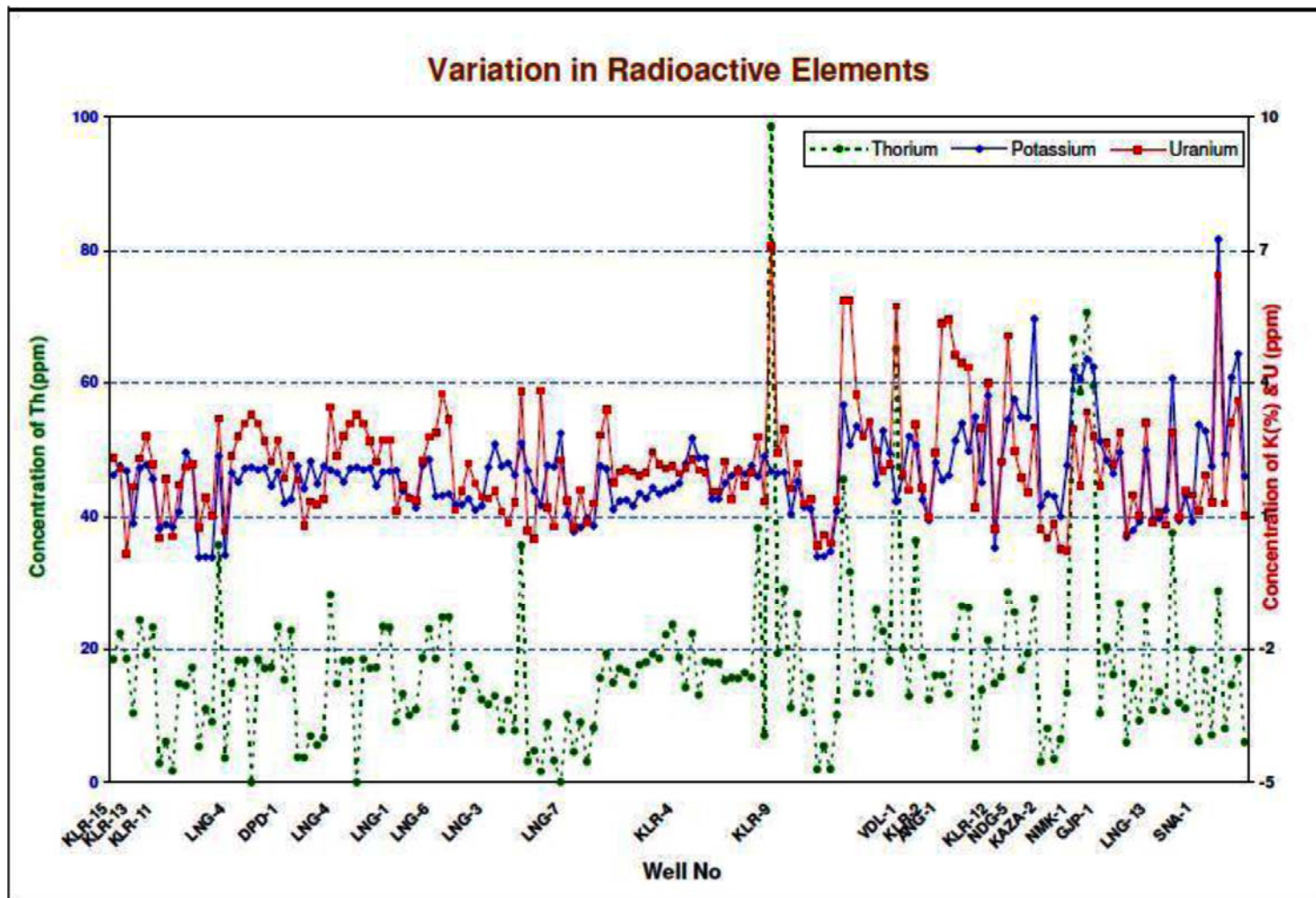


Figure 2. Distribution of thorium, uranium and potassium.

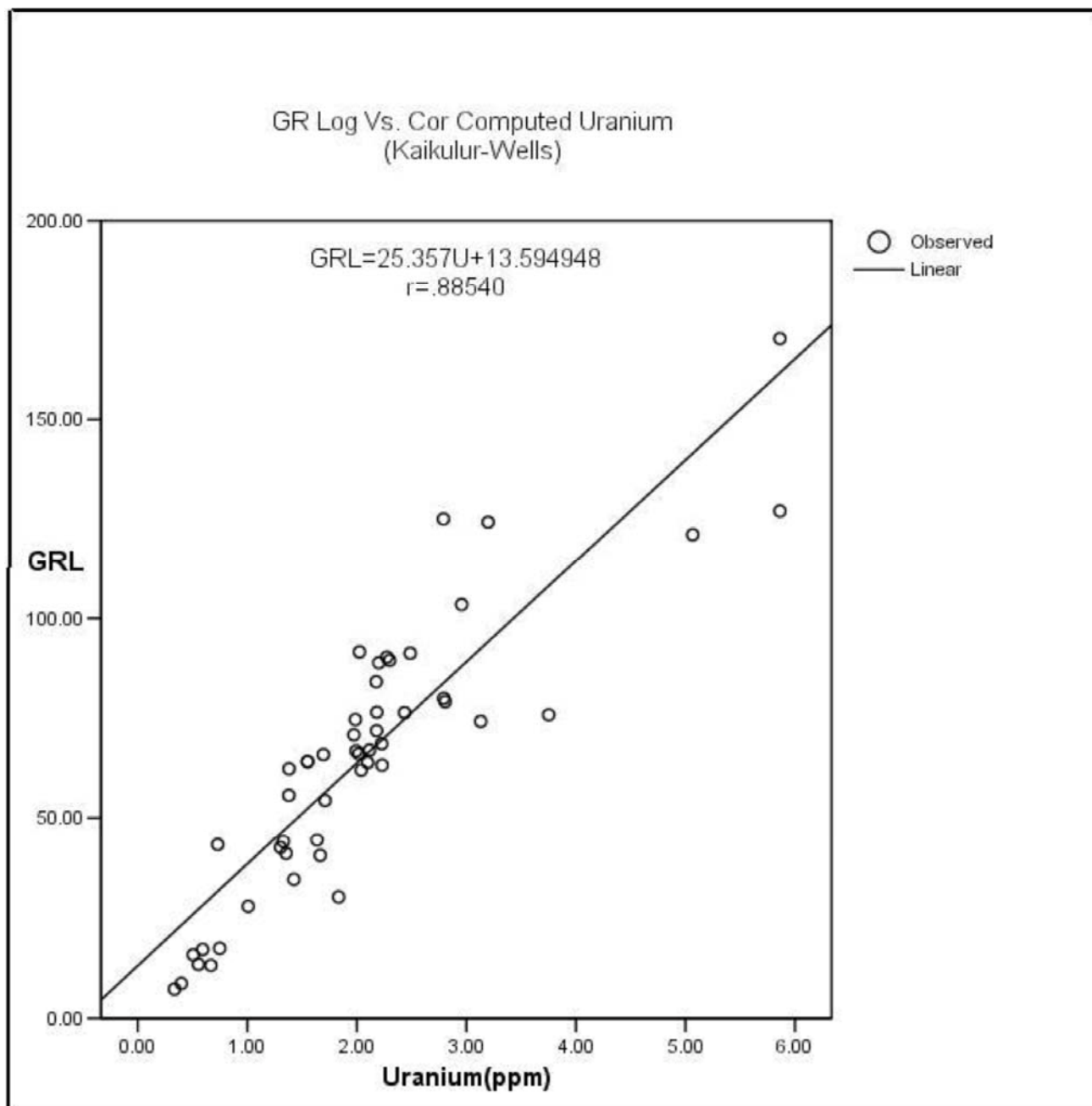


Figure 3. GR log vs. core computed uranium for Kaikukur wells.

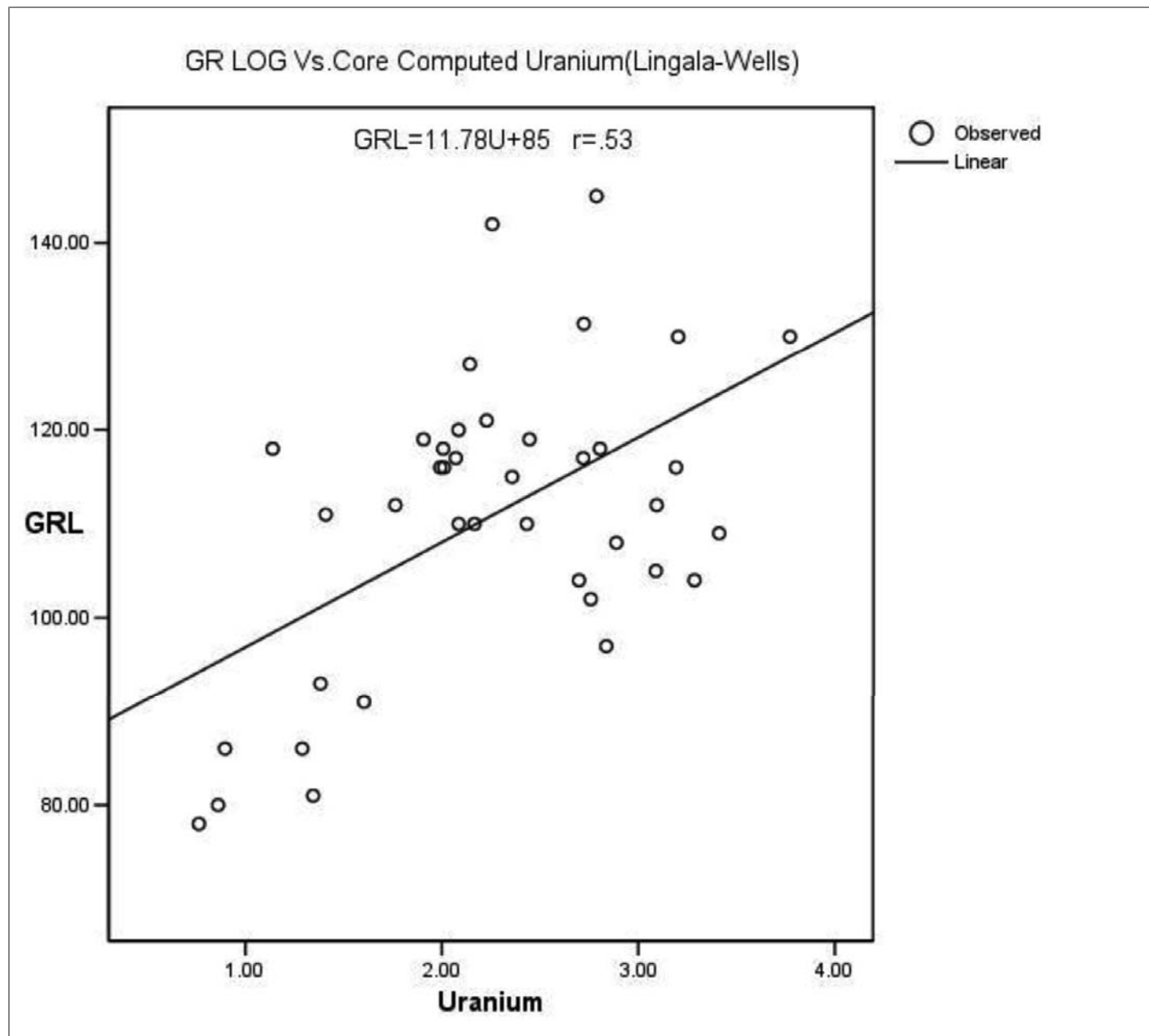


Figure 4. GR log vs. core computed uranium for Lingala wells.

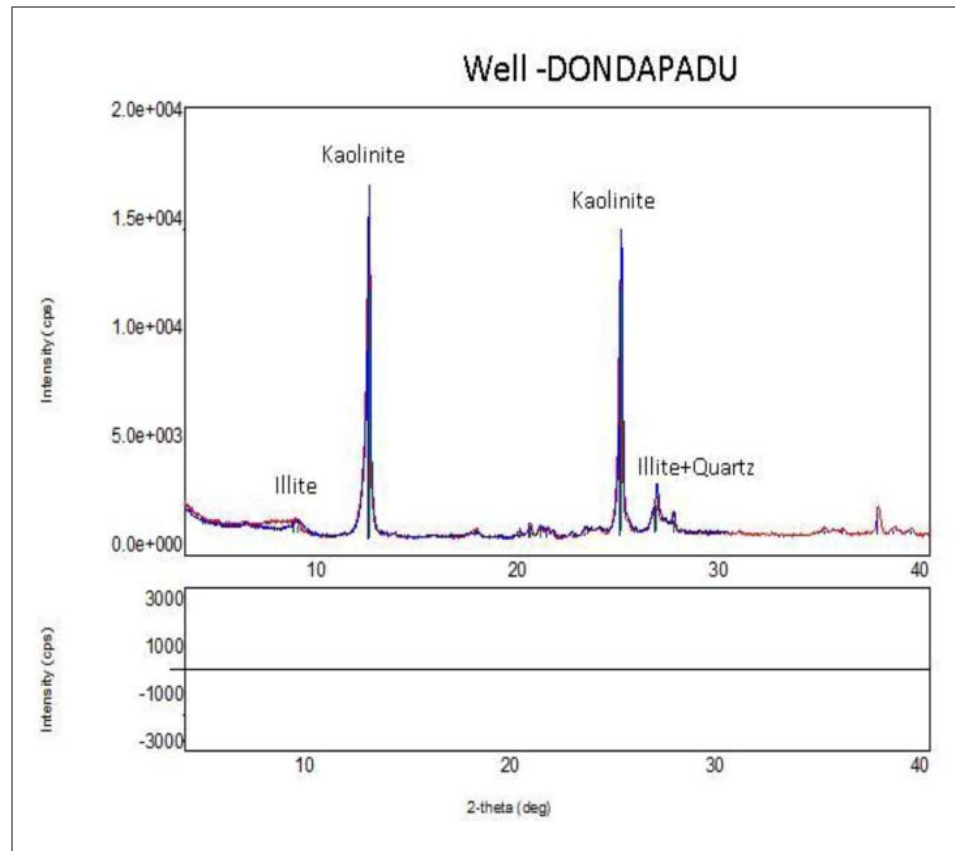


Figure 5. XRD of core sample from one of the wells of Dondapadu.

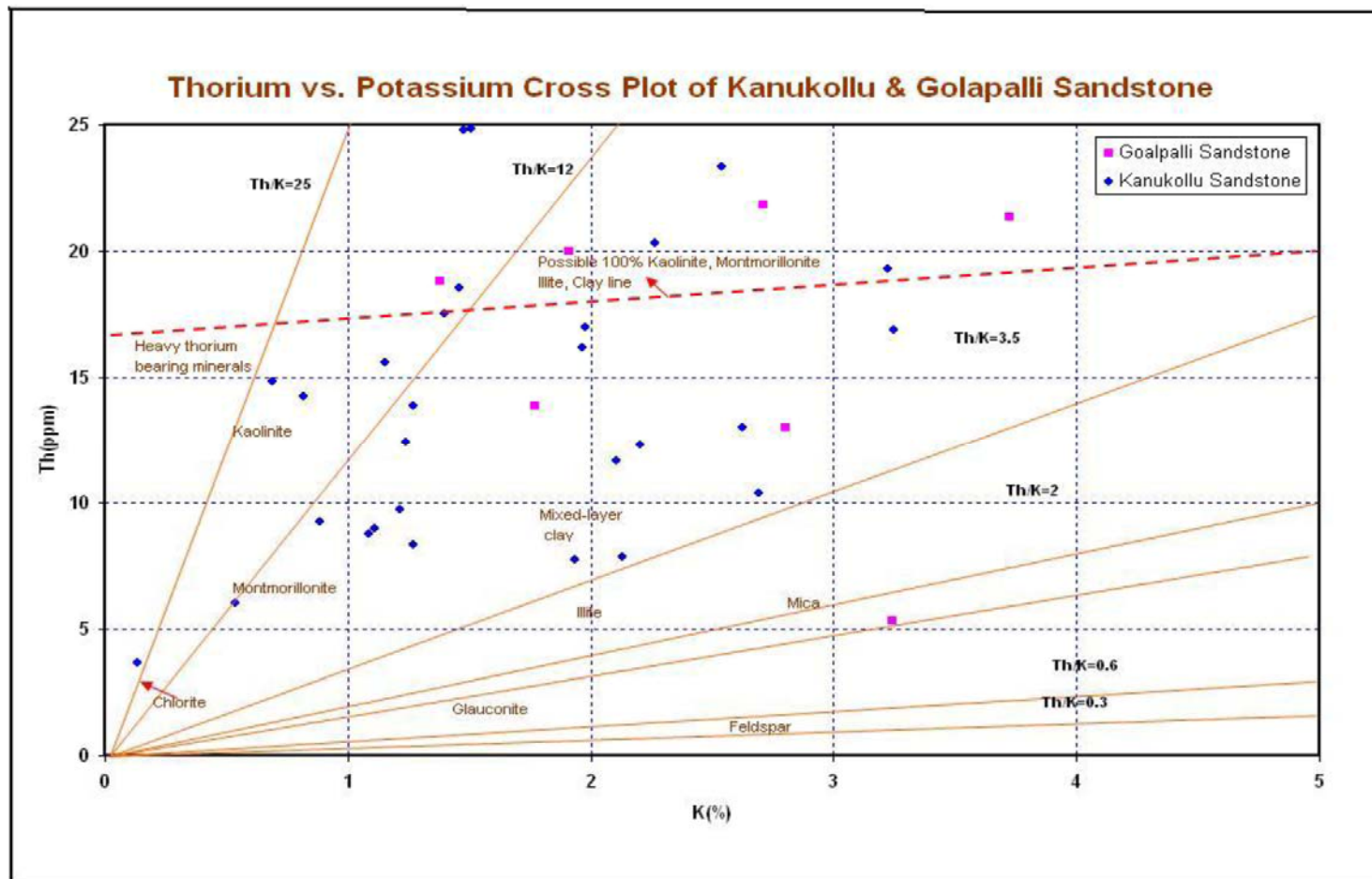


Figure 6. Clay typing.