Radiometry Analysis of Alluvial Deposits Samples Collected from Sharm El-Sheikh Area, Southern Sinai. Egypt

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ABSTRACT
At Sharm El-Sheikh area, alluvial deposits derived from younger granites which exhibit association of important minerals (alkali feldspar, plagioclase feldspar, quartz, allanite, zircon, monazite chevkinite and magnetite) were subjected to radiometry measurements using HP-Ge detector. Activity concentrations of the radionuclides were found to be near to each other except ⁴⁰K which measure high values. Element content of thorium and uranium (eTh & eU) was calculated to estimate uranium migration (in / out) process for the studied locality. Most of the studied samples were found belong to forbidden zone except samples Yg9 & Yg10. The results indicated migration of uranium in percent ranges from 7.31% to 32.51% for the locality of the collected and studied samples. Detrital ²³⁰Th was calculated to determine the corrected ²³⁰Thₜ and applied to ²³⁰Th/²³⁴U dating which found to range between, 27 to 28 Ky. Migration time was also calculated using uranium original values.

Keywords: Alluvial deposits, Hp-Ge detector, Uranium dating, Uranium migration.

1. Introduction
In southern Sinai, granitic rocks are more predominant than any other area of the Arabian Nubian Shield (ANS), including ~70% of the exposed basement complex (Bentor, 1985). The granitic rocks of the ANS comprise two main varieties: (1) older granites (620–820 My) involve Calc-alkaline I-type granitic rocks (quartz diorite- granodiorite) that were generated in orogenic volcanic arc tectonic regime (Hussein et al., 1982; Hassan and Hashad, 1990 & Helal and Samir, 2008) and (2) younger granites (590–610 My) including highly fractionated Calc-alkaline I-type and alkaline A-type granites, and generated in post collisional tectonic setting of the shield creation (Hassan and Hashad, 1990; Beyth et al., 1994; Ali et al., 2009; Eyal et al., 2010 and Eyal et al., 2014).

The alluvial deposits (stream sediments) are the weathering products of various types of granitic rocks of younger granite types which is the dominant rock unit exposed in the studied area.

The granites are mainly composed of potash feldspar, plagioclase feldspar, quartz, mafic minerals (biotite + amphibole) and accessories (titanite, epidote, zircon, allanite, magnetite and opaques). These minerals are the main components of the alluvial deposits in the studied area.

It is well known that thorium, has opposed property to uranium which considered to be immobile in the weathering environment, on the other hand thorium undergo variation as a result of magnetic process more effective than uranium variations (Nash, 1979).

The primary sources of natural radioactivity in rock and soil are radionuclides of the elements uranium, thorium, and potassium (referred to as radioelements), specifically the uranium-238, thorium-232, decay chains and potassium-40.

Thorium is a naturally occurring, slightly radioactive element. It is found in small amounts in most rocks, where it is about three times abundant than uranium. Granitic rocks show a distinct increase over mafic igneous rocks, averaging 20–30 ppm. (Nash, 1979).

The transformation of neutral radioactive nuclei present in different types of rocks results in other radioactive isotopes as well, where the concentrations of the latter depend on the age of rocks as
well as of their half-life. Radioactive equilibrium expected occurred between parents and their daughters for isolated types of rocks, but due to mobility of some isotopes rather than others causes disequilibrium and unequal activity concentrations will be observed. The present study, the content of thorium and uranium in the derived alluvial streaming sediments from various types of younger granitic rocks was investigated to estimate the age and uranium migration process occurred at the past time in the studied area.

2. Geologic Setting

The exposed Neoproterozoic basement complex of the studied area shown in Fig.1 is classified from oldest to youngest as follows: (Sherif et al., 2013) 1- Older granite (G 1) 2- Metavolcanics (Dokhan), and 3- younger granites of (G 2) (phase, II& III= Alkali feldspar granite and III= Riebeckite granite), is the youngest rock unit in the studied area and intruded into the earlier phases GI and GII granites.

![Geologic map of the studied area.](image)

Fig. 1: Geologic map of the studied area.

Metavolcanics are rare in the studied area Fig. 2, they range in compositions from mafic to felsic. These volcanic rocks are effectiveness in alluvial deposits composition.

3. Methodology

3.1. Sampling

Dry stream sediments samples (alluvial deposits) were collected with interval of about 400m. The proper samples were picked at depth 30-50 cm with size fraction less than 1 mm and sample weight was about 20-25 Kg, each sample was quartered to reach a proper representative weight (1000 gm). The collected fraction is a representative of dominant Precambrian granites outcropping in the studied area. Notes were taken at the sample site including location, any unusual sediment, and any indication of contamination and character of sediments. Fig. 2 is displaying the sample location map of the collected samples.

3.2. HP-Ge detector and γ-ray spectrometry

The samples were analysed non-destructively, using gamma-ray spectrometry with a high-purity germanium (HP- Ge) detector. This detector has a relative efficiency of approximately 50% of the 3” x 3” NaI (Tl) crystal efficiency, with a resolution of 1.90 keV and a peak/Compton ratio of 69.9:1 at the 1.33 MeV gamma-ray transition of $^{60}$Co. The detector is coupled to conventional electronics and connected to a multi-channel analyser (MCA) card installed in a personal computer (PC). The detector is shielded from the background radiation, using a 10-cm thick lead shield, internally lined with a 2-mm thick copper foil. The software program MAESTRO-32 was used to accumulate and analyse the data. The system is calibrated for energy to display gamma-ray photo-peaks between 63 and 3000
The efficiency calibration was performed by using three well-known reference materials obtained from the International Atomic Energy Agency for the U, Th and K activity measurements: RGU-1, RGTh-1 and RGK-1, respectively (IAEA 1987, Anjos et al., 2005 & El Aassy et al., 2011).

The uranium-238 activity was determined indirectly from analysing the gamma rays emitted by its daughter product ($^{234}$Pa) determined from the 1001 keV photo-peak, (Sutherland and deJong, 1990). The activity of $^{234}$U was determined from the gamma rays emitted by this nuclide at energy of 120.9 (0.0342%) keV (after the subtraction of the 120.35 keV peak of $^{235}$U), the uranium-235 activity was determined by its gamma ray photo-peaks: 143.8, 163.4, 185.7 and 205.3 keV (Rameb¨ack et al., 2010). The activity of $^{230}$Th was determined from the 67.7 (3.77%) keV peak (Simpson, 1998). The specific activity of $^{40}$K was measured by its own gamma-ray emission at 1460.8 keV. The specific activity of $^{226}$Ra was measured using the 186.1 keV peak from its own gamma-ray emission (after the subtraction of the 185.7 keV peak of $^{235}$U). The specific activity of $^{214}$Pb was measured using the 295.2 keV and 351.9 keV peaks, whereas the specific activity of $^{214}$Bi was measured using the 609.3 keV peak. The specific activity of $^{232}$Th was measured using the 338.4 keV and 911.2 keV peaks for $^{228}$Ac and the 583 keV and 2614.4 keV peaks for $^{208}$Tl (El Aassy et al., 2017).

3.3. Gamma measurements

The collected samples were crushed and ground to approximately (60 µm) to obtain representative samples for performing the experiments and analyses. The samples were measured by $\gamma$-spectrometry using a hyper-pure germanium detector to determine the activity concentrations in units of Bq/kg for $^{238}$U, $^{235}$U, $^{226}$Ra, $^{232}$Th and $^{40}$K.

For the radiometric analysis, each dried sample was splattered by quartering, weighed and transferred to 200-ml capacity polyethylene Marinelli beaker, then sealed and stored for four to eight weeks to both prevent the escape of the radiogenic gases ($^{222}$Rn and $^{220}$Rn) and to allow the attainment of radioactive equilibrium in the decay chain. After equilibrium has been reached among short lived isotopes and their progenies, the samples were subjected to gamma-ray spectrometric analysis. Each sample was measured during an accumulation time between 20 h and 24 h. After the measurement of each sample, an empty cylindrical plastic container (polyethylene Marinelli beaker) was placed in the detection system for a counting period of 48 h to collect the background count rates.
3.4. Radioactivity counting

The net area count after background corrections in each photo-peak was used in the computation of the activity concentration \( C \) in units of Bq kg\(^{-1} \) for each of the radionuclides in the samples using the following expression, (Jibiri et al., 2007).

\[
C(\text{Bq Kg}^{-1}) = \frac{C_n}{\varepsilon P_{\gamma} M_s}
\]

(1)

Where \( C_n \) is the count rate under each photo-peak due to each radionuclide, \( \varepsilon \) is the detector efficiency for the specific \( \gamma \)-ray, \( P_{\gamma} \) is the absolute transition probability of the specific \( \gamma \)-ray, and \( M_s \) is the mass of the sample (kg). The lowest limits of detection (LLD) were obtained from the relation (Jibiri and Bankole, 2006; Akram et al., 2006).

\[
\text{LLD} = \frac{4.66 S_b}{\varepsilon I_{\gamma}}
\]

(2)

Where \( S_b \) is the estimated standard error of the net background count rate in the spectrum of the radionuclide and \( I_{\gamma} \) is the abundance of gamma emissions per radioactive decay. The LLD values obtained were 9.347, 1.307 and 1.344 Bq kg\(^{-1} \) for \(^{40}\text{K} \), \(^{238}\text{U} \) and \(^{232}\text{Th} \), respectively.

Uranium migration in percent (Um %) is given by (NMA, 1999).

\[
Um\% = \left( \frac{U_m}{U_p} \right) \times 100
\]

(3)

Where \( U_p \) is the average measured eU, and Um is given by:

\[
U_m = U_p - U_o
\]

(4)

\( U_o \) is given by:

\[
U_o = \frac{eTh}{\text{regional} \left( \frac{eTh}{eU} \right)}
\]

(5)

The studied area is characterized by regional \( \frac{eTh}{eU} = 3.5 \sim 4 \) (Mohammed et al., 2018).

4. Results and Discussion

4.1. Microscopic identification of the source rock (granite) of the alluvial deposits

Microscopically, the granites compose mainly of alkali feldspar (sanidine (K AlSi\(_3\)O\(_8\))), plagioclase feldspar minerals (albite (NaAlSi\(_3\)O\(_8\))) or oligoclase ((Na,Ca) AlSi\(_3\)O\(_8\)) and quartz (SiO\(_2\)). In some cases, the rocks are composed of quartz, albite and microcline perthite, saussuritized oligoclase, riebeckite and biotite. The accessory phases include apatite ((3Ca\(_3\) (PO\(_4\))\(_2\).CaF\(_2\))), Zircon ZrSiO\(_4\), Monazite (Ce, La, Th) PO\(_4\), Thorite ThSiO\(_4\) and opaques which mainly represented by magnetite (Fe\(_3\)O\(_4\)) as displayed in a group of Figs 3. A - D.
Fig. 3: (A) Large perthite crystal displaying veinlet type of perthitic intergrowth, (B) Association of quartz (Qz) crystals and plagioclase crystals (Plag), (C) Large subhedral biotite flake (Biot) enclosing fine crystals of chevkinite (Chev) and Thorite(Thor) and (D) Association of riebeckite (Rieb), allanite (Allan) and magnetite (Mag).

4.2. Activity Concentrations

The activity concentration values of different radionuclides $^{238}\text{U}$, $^{234}\text{U}$, $^{230}\text{Th}$, $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in the ten samples were calculated using gamma counting and listed in Table 1. Activity concentrations shown in Table 1 are displayed in Figs. 4, 5, &6 for different radionuclides.

Calculation of expected original values of uranium and the uranium migrated percent in the different samples were calculated using (equation 5) from equivalent uranium and thorium $\text{eU}$ & $\text{eTh}$ with uranium recorded in Table 2, activities ratios of $^{234}\text{U}/^{238}\text{U}$, $^{230}\text{Th}/^{234}\text{U}$ & $^{234}\text{U}/^{232}\text{Th}$ were listed also in the same table.

As shown in Figs 4-7 activities of different radionuclides were near to each other except activity of $^{40}\text{K}$ was found to be high and this is in agreement with characteristics of alluvial deposits, which being rich in potassium (K) and abundant in most terrestrial and extra-terrestrial rocks (Cassata, 2012). Measured activity concentrations were recorded with lower values than other radionuclides for all studied alluvial deposits samples.

Fig. 4: The activity distributions of the $^{238}\text{U}$, $^{234}\text{U}$, $^{230}\text{Th}$ & $^{232}\text{Th}$ radionuclides in the samples
Table 1: Activity concentrations of different studied samples using gamma counting recorded by HP-Ge.

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yg1</td>
<td>49.47±2.03</td>
<td>49.22±1.93</td>
<td>46.81±2.10</td>
<td>57.39±4.66</td>
<td>56.75±4.92</td>
<td>45.33±3.88</td>
<td>47.71±1.19</td>
<td>979.93±11.36</td>
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<tr>
<td>Yg2</td>
<td>28.52±5.26</td>
<td>28.49±1.58</td>
<td>26.81±1.45</td>
<td>31.36±1.69</td>
<td>31.98±1.84</td>
<td>27.78±2.61</td>
<td>27.13±3.04</td>
<td>1112.54±33.57</td>
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<tr>
<td>Yg3</td>
<td>34.78±1.75</td>
<td>36.21±2.33</td>
<td>31.06±2.09</td>
<td>46.49±3.47</td>
<td>42.05±2.13</td>
<td>42.42±3.44</td>
<td>30.59±2.11</td>
<td>1165.06±51.31</td>
</tr>
<tr>
<td>Yg4</td>
<td>40.05±8.31</td>
<td>39.11±3.14</td>
<td>37.17±3.71</td>
<td>44.96±5.63</td>
<td>43.19±3.08</td>
<td>40.95±4.75</td>
<td>38.05±4.26</td>
<td>1172.13±62.78</td>
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<tr>
<td>Yg5</td>
<td>52.81±3.89</td>
<td>53.07±4.06</td>
<td>48.98±1.89</td>
<td>58.20±4.77</td>
<td>46.59±4.24</td>
<td>42.77±2.86</td>
<td>49.56±3.17</td>
<td>1175.92±85.23</td>
</tr>
<tr>
<td>Yg6</td>
<td>31.17±5.26</td>
<td>32.11±2.84</td>
<td>32.01±2.37</td>
<td>37.64±2.48</td>
<td>36.23±2.33</td>
<td>32.76±1.74</td>
<td>33.01±2.04</td>
<td>1335.05±45.08</td>
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<tr>
<td>Yg7</td>
<td>39.11±2.56</td>
<td>38.92±1.88</td>
<td>36.85±1.09</td>
<td>44.21±3.75</td>
<td>40.81±3.98</td>
<td>42.77±4.06</td>
<td>37.40±4.05</td>
<td>1398.07±93.06</td>
</tr>
<tr>
<td>Yg8</td>
<td>49.19±1.23</td>
<td>46.38±2.53</td>
<td>44.60±1.25</td>
<td>53.96±4.62</td>
<td>48.04±4.55</td>
<td>52.24±2.55</td>
<td>45.53±5.22</td>
<td>1406.56±41.39</td>
</tr>
<tr>
<td>Yg9</td>
<td>63.37±3.87</td>
<td>67.12±4.40</td>
<td>57.11±3.78</td>
<td>69.84±5.81</td>
<td>51.56±2.34</td>
<td>49.18±4.10</td>
<td>55.81±6.07</td>
<td>1411.10±61.07</td>
</tr>
<tr>
<td>Yg10</td>
<td>40.05±2.09</td>
<td>41.78±3.51</td>
<td>40.39±2.15</td>
<td>46.11±2.37</td>
<td>41.38±3.06</td>
<td>39.12±5.20</td>
<td>41.04±4.88</td>
<td>1602.06±86.41</td>
</tr>
</tbody>
</table>

Table 2: Equivalent uranium and thorium (eU & eTh), uranium migration values (ΔU), uranium migration percent(ΔU%) and activities ratios for different studied samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>eU (ppm)</th>
<th>eTh (ppm)</th>
<th>eTh/e U</th>
<th>U0</th>
<th>ΔUm (Bq Kg-1)</th>
<th>ΔUm %</th>
<th>Activity Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
<td>Min</td>
<td>Max</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yg1</td>
<td>3.99</td>
<td>11.81</td>
<td>2.96</td>
<td>3.37</td>
<td>2.95</td>
<td>7.63</td>
<td>12.86</td>
</tr>
<tr>
<td>Yg2</td>
<td>2.30</td>
<td>6.72</td>
<td>2.92</td>
<td>1.92</td>
<td>1.68</td>
<td>4.73</td>
<td>7.70</td>
</tr>
<tr>
<td>Yg3</td>
<td>2.80</td>
<td>7.57</td>
<td>2.70</td>
<td>2.16</td>
<td>1.89</td>
<td>7.95</td>
<td>11.31</td>
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<td>Yg4</td>
<td>3.23</td>
<td>9.42</td>
<td>2.92</td>
<td>2.69</td>
<td>2.35</td>
<td>6.68</td>
<td>10.85</td>
</tr>
<tr>
<td>Yg5</td>
<td>4.26</td>
<td>12.27</td>
<td>2.88</td>
<td>3.50</td>
<td>3.07</td>
<td>9.35</td>
<td>14.78</td>
</tr>
<tr>
<td>Yg6</td>
<td>2.51</td>
<td>8.17</td>
<td>3.25</td>
<td>2.33</td>
<td>2.04</td>
<td>2.22</td>
<td>5.84</td>
</tr>
<tr>
<td>Yg7</td>
<td>3.15</td>
<td>9.26</td>
<td>2.94</td>
<td>2.64</td>
<td>2.31</td>
<td>6.31</td>
<td>10.41</td>
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<tr>
<td>Yg8</td>
<td>3.97</td>
<td>11.27</td>
<td>2.84</td>
<td>3.22</td>
<td>2.82</td>
<td>9.26</td>
<td>14.25</td>
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<td>Yg9</td>
<td>5.11</td>
<td>13.81</td>
<td>2.70</td>
<td>3.95</td>
<td>3.45</td>
<td>14.43</td>
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<td>Yg10</td>
<td>3.23</td>
<td>10.16</td>
<td>3.15</td>
<td>2.90</td>
<td>2.54</td>
<td>4.06</td>
<td>8.56</td>
</tr>
</tbody>
</table>
Fig. 5: The activity distribution of the 226Ra, 214Bi & 214Pb radionuclides in the samples.

Fig. 6: The activity concentration of the $^{40}$K in the samples.

Fig. 7: Thiell diagram of $^{230}$Th/$^{238}$U vs $^{234}$U/$^{238}$U. Most of samples located at forbidden zone and its boundary.
4.3. Uranium Migration

Radiometric determinations of element content for uranium (eU) and thorium (eTh) for different samples were listed in Table 2. Calculation of original maximum and minimum uranium values corresponding to migration percent has been take place using equation 3. Uranium migration occurred to the studied locality, ranges from 2.22 to 20.55 BqKg\(^{-1}\) and the migration percent ranges from 7.13 % to 32.51%. Maximum uranium migration percent was found at sample Yg3 which is the sample mostly exposed to water stream, and this causes the uranium leaching from the surrounding and precipitated in this sample, while the minimum uranium migration percent was found at sample Yg6 which is the most distant sample from exposure to water stream with less chance to transported leached uranium.

4.4. Activity Ratios

Measurements setting of activity concentrations by gamma counting help to keep secular equilibrium among \(^{238}\)U, and its progenies, if it was present in the original collected sample. The relations of the activity ratios between \(^{234}\)U/\(^{238}\)U, \(^{230}\)Th/\(^{238}\)U, \(^{234}\)U/\(^{232}\)Th and \(^{230}\)Th/\(^{232}\)Th are listed in Table 2 and displayed in Fig. 7 which represents Thiel diagram to determine the nature of locality of selected studied alluvial deposits samples (Thiel et al., 1983). Most of studied samples belong to forbidden zone and near this zone boundary except samples Yg9 & Yg10 within the accumulation zone, these samples are exposed to dense water current.

4.5. Time of Alteration

The time of alteration was calculated using equation 6 (Samer et al., 2015):

\[
\frac{^{230}Th}{^{234}U} = \left(1 - e^{\lambda_{^{230}U}t}\right) \tag{6}
\]

To give equation 7:

\[
t = -\lambda_{^{230}Th}^{-1} \ln \left(1 - \frac{^{230}Th}{^{234}U}\right) \tag{7}
\]

Thorium indicated in Equation 6 is radiogenic \(^{230}\)Th as decay product of \(^{234}\)U so it should be first calculate the detrital \(^{230}\)Th\(_{d}\) such that the measured total thorium

\[
^{230}\text{Th} = ^{230}\text{Th}_{d} + ^{230}\text{Th}_{a}
\]

\(^{230}\)Th\(_d\) was calculated from the relation of \(^{230}\)Th/\(^{232}\)Th & \(^{234}\)U/\(^{232}\)Th activities ratios, as the Y intersection at \(^{234}\)U activity equal zero (Kaufman et al., 1965 & Mebus, 2001).

Equation 8 represent the formulae of line shown in Fig. 8:

\[
\frac{^{230}Th}{^{232}Th} = 0.23 \frac{^{234}U}{^{232}Th} + 0.75 \tag{8}
\]

The time of alteration processes for different samples was calculated from equation 7 using the corrected \(^{230}\)Th after subtraction the \(^{230}\)Th\(_d\) as listed in Table 3. Time of migration has been calculated and recorded in Table 4.

Migration time has good correlation with \(^{234}\)U as shown in Fig. 9 current activity, such that the activity of \(^{234}\)U is growing up by time as \(^{238}\)U decayed.
Table 3: Time of alteration for the studied samples using corrected $^{230}$Th.

<table>
<thead>
<tr>
<th>Sample</th>
<th>$^{230}$Thd</th>
<th>$^{230}$Th (corrected)</th>
<th>$^{230}$Th/$^{234}$U</th>
<th>$^{230}$Th/$^{234}$U</th>
<th>Age (Ky)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yg1</td>
<td>35.783</td>
<td>11.0275</td>
<td>0.224</td>
<td>0.776</td>
<td>27.60</td>
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<td>Yg2</td>
<td>20.348</td>
<td>6.4625</td>
<td>0.227</td>
<td>0.773</td>
<td>27.99</td>
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<td>Yg3</td>
<td>22.943</td>
<td>8.1175</td>
<td>0.224</td>
<td>0.776</td>
<td>27.62</td>
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<td>Yg4</td>
<td>28.538</td>
<td>8.6325</td>
<td>0.221</td>
<td>0.779</td>
<td>27.13</td>
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<td>Yg5</td>
<td>37.170</td>
<td>11.8100</td>
<td>0.223</td>
<td>0.777</td>
<td>27.39</td>
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<td>Yg6</td>
<td>24.758</td>
<td>7.2525</td>
<td>0.226</td>
<td>0.774</td>
<td>27.85</td>
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<td>Yg7</td>
<td>28.050</td>
<td>8.8000</td>
<td>0.226</td>
<td>0.774</td>
<td>27.89</td>
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<td>Yg8</td>
<td>34.148</td>
<td>10.4525</td>
<td>0.225</td>
<td>0.775</td>
<td>27.78</td>
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<td>Yg9</td>
<td>41.858</td>
<td>15.2525</td>
<td>0.227</td>
<td>0.773</td>
<td>28.05</td>
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<tr>
<td>Yg10</td>
<td>30.780</td>
<td>9.6100</td>
<td>0.230</td>
<td>0.770</td>
<td>28.44</td>
</tr>
</tbody>
</table>

Table 4: Time of migration for the studied samples using originated $^{234}$U.

<table>
<thead>
<tr>
<th>Sample</th>
<th>$^{230}$Th/$^{234}$U</th>
<th>Age (Ky)</th>
<th>$^{234}$U (migrated)</th>
<th>Age (Ky) (migrated)</th>
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<td>Max.</td>
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Fig. 8: $^{230}$Th/$^{232}$Th vs $^{234}$U/$^{232}$Th curve to deduce corrected $^{230}$Th.
5. Conclusions

In the present study, microscopic identification of the source rocks and radioactivity levels of radionuclides were determined using gamma-ray spectrometer with high purity germanium detector. Moreover, the determination uranium migration values and percent for each of the studied samples, to obtain the migration percent which was found to be migration in process. The obtained results show maximum activity for $^{40}$K; the activity concentration values of $^{238}$U & $^{232}$Th and their progeny were detected in all samples but lower than $^{40}$K. Low activity of uranium and its progeny for the selected studied samples was observed, therefore it is safe to uses as row material in industry.

Time of alteration processes within the studied samples was calculated results shows the average of this time ranges from 27 to 28 Ky. Time intervals within which the uranium migration occurred has been calculated by using original values of uranium.

References


