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Thermoluminescence Properties of Some Jizan Soil

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ABSTRACT. Thermoluminescence (TL) response of some Jizan sandy soil to γ rays was studied. Experimental results indicated that highest TL response belongs to fine grain sandy soil samples and lowest TL response is observed for sandy soil samples contaminated with silt. Furthermore, TL response was found to vary linearly with the square root of (silicium-dioxide content to the sum of aluminium oxide plus iron oxide contents) in the sandy soil samples. Relative response of Jizan sandy soil samples to TLD-700 crystal is found to vary from 1.8×10^{-2} down to 7.3×10^{-3}.

Thermoluminescence response of some geological materials was reported by Mejdahl (1968). TL dosimetry using natural materials was previously reported by Gomaa and Eid (1976), TL dosimetry using fused silica was reported by Gomaa and Morsi (1976). TL applications of heated sand was reported by Gomaa and Eid (1977). The main aim of the current work was to investigate the thermoluminescence properties of sandy soil.

Theoretical Considerations

When a TL phosphor, such as LiF:Dy crystals or natural TL material such as sand, is exposed to γ-rays at a sufficiently low temperature many of the free electrons (resulting from photo-electric, compton and pair production interactions) or holes become trapped at lattice imperfection in the crystalline solid. They remain trapped for long periods of time when stored at low temperature. If the temperature is raised the probability of escape is increased and the electrons (or holes) are released from the traps, subsequently returning to stable energy states with the emission of light. If the light intensity is measured and plotted as a function of the temperature the resulting graph is called a glow curve. Typical glow curves exhibit one or more maxima as traps of various energy "depth" are emptied. For more details about theory of TL Phosphorescence and electron traps see Randall and Wilkins (1945). The mathematical expression of the escape probability is related with the trap depth by:

$$P = s \exp(-E / kT)$$

where P is the escape probability,
s is the frequency factor in 1/second
E is the trap depth in J.,
T is the temperature in Kelvin, and
k is Boltzmann constant in J/K.

In general, TL materials are classified into natural materials which characterize with many trap depths and many TL peaks, and TL-man made materials which characterize with one or two TL peaks. Furthermore, light output is related to integrated exposure due to ionizing radiation. The main aim of the present investigation was to study the soil chemistry of some Jizan sand and its TL response to γ rays.

Jizan Sandy Soil Samples

Seven different samples of Jizan soil were collected for soil chemistry and TL response to γ-rays. These soil samples were collected from the central part of Jizan region. Jizan region is located at the south east of the Kingdom of Saudi Arabia. In details, soil samples were collected from Rayan village and Khabt Said village. The latter area is located at 27°N and 42°50′E and it is more than 30 km away from the sea shore of the red sea. Rayan and Khabt Said villages are characterized as agriculture land.

Soil Samples Selection

Soil samples numbers one and two are selected from a location 2 km East to Rayan village. The first sample (yellow to red in colour) is known Hameriah locally. The second type is known Jalaiah locally. Both types are composed of silt and fine grain sand. Furthermore, the second soil sample is also characterized with clay. Soil samples numbers 3 and 4 are selected from a location 3 km south east of Rayan village (valley). Soil sample number 3 is mainly coarse sand in mixture with silt while soil sample number 4 is mainly fine sand in mixture with silt. In general, soil samples numbers 3 and 4 are in use as building materials in Jizan region. Soil sample number 5 is collected from a location east to Khabt Said village and this area is known locally as red edge region. Soil samples numbers 6 and 7 are collected from a location west of Khabt Said village. Sample number 6 is fine grain sandy soil while soil sample number 7 is compact mass sandy soil. In the present study, the classifications of soil particle-size group of Donahue *et al.* (1983) was followed.

Soil Chemistry

Chemical analysis of soil samples was carried out following the techniques of Faniran and Areola (1978). In Table 1 the following informations are included:

1. Carbonate in milli-equivalent percent,
2. Organic matter in milli-equivalent percent,
3. Organic carbon in milli-equivalent percent,
4. Total nitrogen in milli-equivalent percent,
5. Cation exchange capacity in milli-equivalent percent, and
6. Electrical conductivity in μmho cm^{-1}

Table 1. Soil chemistry for sandy soil samples

Sample No.	CO_3^{--} meq%	Organic matter meq%	Organic carbon meq%	Total N_2 meq%	Cation exchange capacity meq%	Elec. cond. $\mu\upsilon$/cm
1	1.84±0.84	1.16±0.21	0.59±0.12	0.45±0.17	42.46±1.09	140±25
2	1.83	0.59	0.18	0.75	39.42	–
3	3.18	1.26	0.73	0.41	40.51	–
4	1.53	1.92	1.17	0.49	38.49	–
5	1.66	2.37	1.37	0.40	47.29	–
6	1.32	3.71	2.15	1.55	47.32	–
7	2.40±0.79	0.69±0.26	0.37±0.14	0.22±0.10	37.80±1.0	120±15

The results shown in Table 1 are for unwashed and undried samples.

Chemical analysis of the soil samples were carried out after washing using diluted hydrochloric acid and dyring at 400°C overnight, in order to dehydrate goethite ($Fe(OH)_3$) into hematite Fe_2O_3. In Table 2 the chemical analysis results is shown in oxides form.

From Table 2, it is clear that sample number 4 is sandy (mainly quartz-SiO_2). Highest SiO_2 content is for sample 4 while lowest content is for sample 1. Highest

Al_2O_3 content is for sample 1 and highest Fe_2O_3 content is for sample 6. Careful study of Table 2 indicates that samples 1 and 2 are chemically alike, samples 5 and 7 are also alike and Ti_2O_3 is around 0.6% in all samples. In Table 2, the ratio R = SiO_2/R_2O_3, where $R_2O_3 = Al_2O_3 + Fe_2O_3$. As seen the ratio varies from 2.96 for sample number 1 to 13.14 for sample number 4. The ratio R presented in Table 2 may be useful in interpreting thermoluminescence results.

Thermoluminescence Studies

Soil samples were prepared for thermoluminescence studies by washing with running water for dust removal, hence, with diluted hydrochloric acid for carbonate removal. Furthermore, previous thermoluminescence response to γ-rays are removed by heating at 400°C, hence, slow cooling overnight. Heating at 400°C will remove organic matter as well leaving oxides only in the soil samples. Chemical analysis of soil samples oxides are shown in Table 2.

Table 2. Chemical Analysis of Sandy Soil

Sample No.	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	TiO_2 %	Others %	SiO_2 / R_2O_3	Texture
1	74.0±2	14	11	0.62	0.38	2.96	Fine grains
2	74.5±1	13.5	11	0.60	0.40	3.04	Fine grains
3	88.0±1	7	3	0.57	1.43	8.80	Coarse sand
4	92.0±2	4	3	0.56	0.44	13.14	Fine sand
5	82.0±1	6.2	11	0.60	0.20	4.76	Fine grains
6	76.0±2	9	13	0.59	1.14	3.45	Fine grains
7	81.5±2	6	11	0.60	0.90	4.79	Compact mass

* $R_2O_3 = Al_2O_3 + Fe_2O_3$

Each soil sample was placed in a plastic container of 1cm in diameter and 2.5 cm in height. Hence, containers were placed on the circumference of formed cylinder. At its centre a Cs-137 γ- rays source is located, so that the source centre to container centre is 6 cm. The source activity at the time of measurements was 3.7×10^8Bq (10 MCi). Samples were exposed to 662 KeV γ- rays produced as a result of beta decay of Cs-137 ($Ba^* - 137$ to $Ba - 137$ transitions) for 650 hr. The estimated absorbed dose in air is 5.4 Gy (540 rad) according to the source certificate the used gamma constant is as reported by the source certificate = (0.336 ± where 0.007) $\times 10^{-3} R \cdot h^{-1} m^2 \cdot mCi^{-1}$ and rad to R value as 0.871.

All samples were kept for two days before thermoluminescence reading in order to allow quick fading of the shallow traps. TL signals are recorded in nanocoulomb (nC) using Harshaw 2000 (A+B) TL system. The heating time was kept constant during all measurements at 30 sec only, the maximum heating temperature was at 315°C. Previous experience by Gomaa and Eid (1976) indicated that sand TL peaks are at around 110°C and near 280°C. The TL built in vibrated powder dispenser is used to ensure constant mass of soil, each sample is 17 mg and the heating rate is around 10.6°C/s.

In Table 3, thermoluminescence results in nanocoulomb units. In general, the heating time is 30 sec at uniform rate of 10.6°C/s.

Table 3. TL of soil samples

Sample No.	TL Signal in nC	Relative response
1	56 ± 5	0.10 nC/rad
2	56 ± 4	0.10 nC/rad
3	102 ± 8	0.19 nC/rad
4	137 ± 10	0.25 nC/rad
5	81 ± 5	0.15 nC/rad
6	66 ± 6	0.12 nC/rad
7	81 ± 5	0.12 nC/rad

The average error was calculated according to the following relation:

$$\sigma_{X_i} = \frac{\Sigma |X_i - X|}{n}$$

where X_i is the TL reading for i^{th} sample,

X is the mean TL reading,

n is the number of samples recorded.

In general 15 samples (17 mg each) were read out for each soil sample. TL readings deviated largely from the mean value are neglected.

In Table 3, maximum TL response is for sample 4, while minimum TL response is for samples 1 and 2. In general TL response increases with SiO_2 content (see Table 2).

In the same Table 3 the relative TL response in nC/rad is reported. In order to make use of the relative response results it should be compared with relative response of thermoluminescence crystals currently in use for radiation dosimetric measurements such as TLD-700. The relative response of the in-used crystals at the time of measurements is around 13.7±.5 nC/rad. Hence relative response of Jizan sand soil relative to TLD-700 vary from 7.3×10^{-3} to 1.8×10^{-2}.

The used TL system is not provided with X − Y plotter for TL glow curve plotting. Variation of TL signals with temperature were recorded. Noting that same sample was used for TL readings several times but for longer heating time, *i.e.* to higher tray temperature. Variation of TL signal with heating time is reported in Table 4 for samples 1 and 4.

From Table 4, it is clear that the main TL peak temperature is at 100 to 150°C. Furthermore, the ratio of TL signals for samples 4 to 1 at peak temperature (100 to 150°C) is close to the ratio of TL signals for samples 4 and 1 reported in Table 3 (integrated method).

Discussion and Conclusion

Experimental results, presented in the present work, indicate dependence of thermoluminescence response to γ rays on composition. This is shown in the results reported in Table 3 and also in the results reported in Table 4.

In general maximum thermoluminescence response is found for soil sample number 4 and at tray temperature (100 to 150°C), see Table 4.

Dependence of thermoluminescence signals on chemical composition is reported in the last column of Table 3. Fig. (1-a) shows variation of TL response with SiO_2 percentage. From Figure (1-a) it is clear that TL signal increases with SiO_2% linearly according to $TL = 4.08X_i - 253$, where TL is nC and X_i is the SiO_2

Table 4. Variation of TL signal with heating time for samples one and four

Heating time s	Max. tray temperature °C	TL signal in nC*	
		Sample 1	Sample 4
10	100	7.0	8.6
15	150	26.5	54.7
20	205	11.6	24.4
25	260	6.2	12.3
30	315	5.3	6.8

* After background reduction.

percentage in the sample. While Fig. (1−b) shows variation of TL response with $R^{\frac{1}{2}}$, where R is the ratio

$$R = \frac{SiO_2}{R_2O_3}, \quad R_2O_3 = Al_2O_3 + Fe_2O_3$$

From Figure (1-b), it is clear that TL signal increases with $R^{\frac{1}{2}}$ linearly according to

$$TL = 34.5. \ R^{\frac{1}{2}} - 6$$

where TL is in nC units.

In general, soil samples with high iron oxides amount are characterized with low thermoluminescence response and soil samples with low iron oxide amount is characterized with high TL response to γ- rays.

The relative response of soil samples for γ- ray dosimetry was estimated relative to TLD-700 from Harshaw. Results indicate that relative response of soil sample numbers 1 and 4 relative to TLD-700 is 7.3×10^{-3} and 1.8×10^{-2} respectively. The minimum detectable absorbed dose is estimated as 16 rads, assuming the minimum detectable absorbed dose is around 2 nC for soil sample number 4. Hence, fine grain Jizan soil which is available in large quantities can be used for intermediate levels for γ- ray dosimetry. In order to enhance TL response to γ- rays, soil fine grain samples should be heated up to 1000°C for several hours. This may decrease the minimum detectable absorbed dose by a factor of ten or more. Future work is aimed to estimate the date of archeological objects in Jizan region using thermoluminescence method of Aitken (1974).

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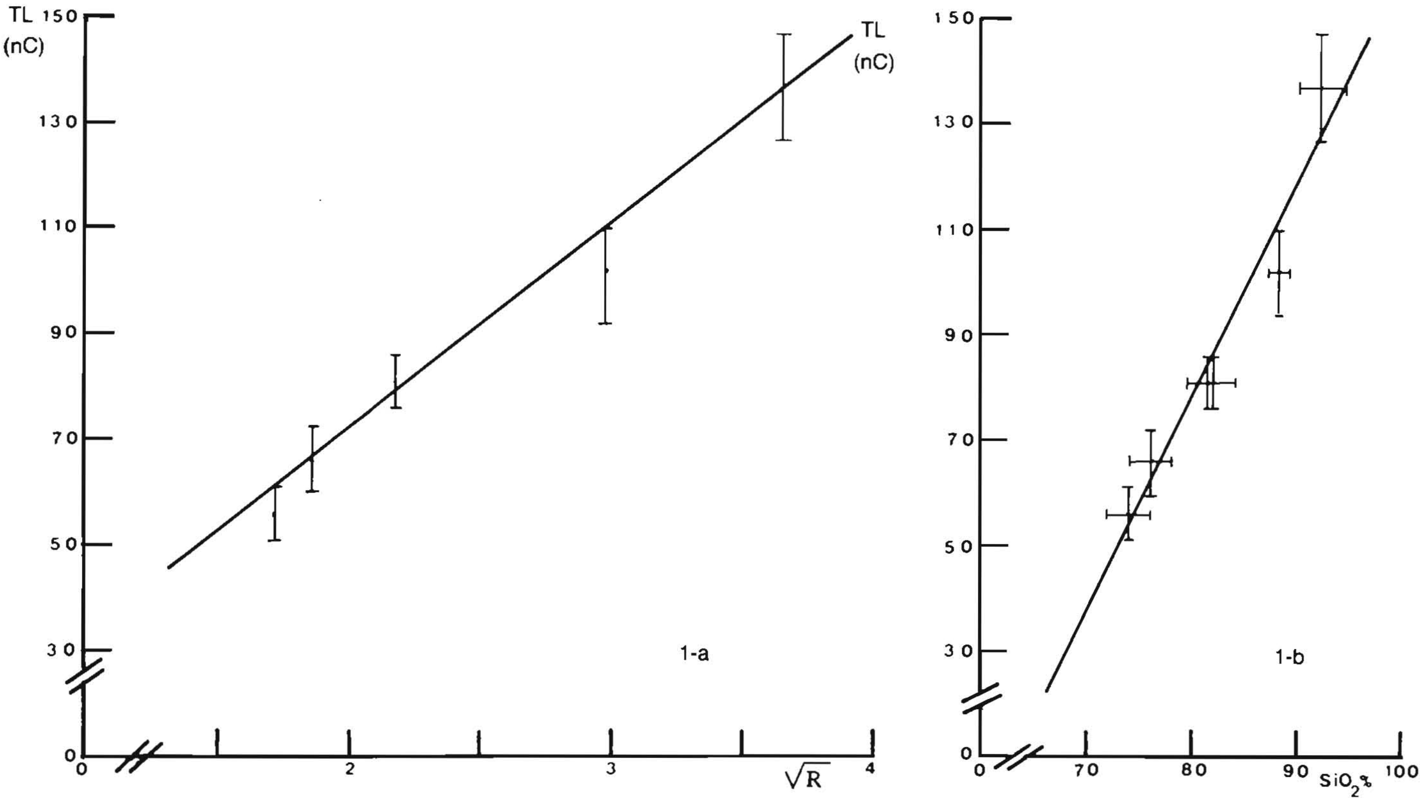

Fig. 1. Variation of TL response (nC) for soil samples from Jizan with SiO_2 percentage (1-a) and $R^{\frac{1}{2}}$ (1-b).

خواص الوميض الحراري لبعض عينات من تربة جيزان

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في هـذا البحث تمت دراسة استجـابة الـوميض الحراري لبعض عينـات من تـربـة جيزان الرملية لأشعة جاما، حيث تم تجميع العينات من تربة الـريان وقـرية خبت سعيد التي تبعد ٣٠ كيلو متراً عن البحر الأحمر. وتمت دراسة كيميـاء التربـة لسبعة عينـات قبل وبعـد تسخين العينـات عند درجـة ٤٠٠°م. واستخدم مصـدر جامـا سيـزيوم ـ ١٣٧ لتعـريض العينات لأشعـة جامـا. كما تم عـد العينات بـاستخدام عداد الوميض الحراري يومين بعد انتهاء التعرض، حيث كان زمن العد ٣٠ ثـانية واقصى درجة حرارة ٣١٥°م ومعدل التسخين ٦, ١٠°م/ ثانية.

كـما تمت مقارنـة الاستجابـة النسبية لهـذه العينات نسبـة إلى عينات الـوميض الحراري التجارية ودلت النتائج عن أن العينة رقم ٤ تعطى أقصى استجابة وميض حراري بين هذه العينات. وهذه العينة جمعت من مـوقع يبعـد ٣ كم جنوب شرق قرية الـريان كـما تم قياس تغير اشارة الـوميض الحراري مـع أقصى درجة حـرارة تسخـين للعينتين رقم (١) ورقم (٤). ودلت النتـائج عـلى أن أعلى إشـارة وميض حراري تصدر عند تسخين العينات إلى ١٠٠°م و ١٥٠°م.

ويوضح الشكـل رقم (١) تغير اشـارة الوميض الحـراري مع $\sqrt{R}$ ، حيث R هي النسبة بين أكسيد السيلكون إلى مجموع أكاسيد الألومنيوم والحديـد في العينة. ومن الشكل يتضح أن العلاقة خطية وتزداد إشارة الوميض الحراري بزيادة $\sqrt{R}$. ويمكن استخدام هذه العينات في تقدير الجرعات الإشعاعية العالية كما يمكن تحسين استجابة هـذه العينات بعـد تسخينها إلى درجـة ١٠٠٠°م وهذا هـو هدف البحث القادم.