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VANADIUM IN SUDANESE PHOSPHATE A CONTRIBUTION TO THE LOCAL ECONOMY

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ABSTRACT
The results of this study were carried out to determine the composition of the vanadium and uranium elements in the Nuba Mountains area in Southern Kordofan region in the regions of Mount Uro and Mount Kurn. Forty samples were collected from the two regions, 20 samples from each region were grinded and converted into powder, and analyzed by XRF spectrometer to find the concentration of each element in the samples. The analysis showed that the average concentration of the uranium element in the samples of Kurn is 103.27ppm, while the average concentration of samples of the Uro area is 985.13ppm, after the operation of the statistical analysis of the results and the average values shows a significant proportion in the global markets. The meta-analysis process shows high concentration of vanadium with an economic importance of more than 80% in most samples. A statistical analysis of the results of the vanadium was performed. The average concentration of vanadium in the samples is Kurn 2793ppm, while the average concentration of vanadium in the samples of the Uro area is 3667.45ppm. Where the prices of both uranium and vanadium have been shown in the world. Markets, it indicates that these concentrations are very important and can contribute to the economy if used properly. It is very interesting to note that the concentration of uranium and vanadium are proportion to each other. This conforms to the hypothesis that these elements may be produced from molten magma which causes heavy elements to reside at the bottom. The percentage of uranium and vanadium agrees with the radioactive decay law, where the decrease of uranium amount, increases vanadium amount..

1. INTRODUCTION
Sudanese land is rich in mineral resources such as (gold, silver, chrome, gypsum. etc). Uranium has been discovered in the area of the Nuba Mountains and Hufrat EL Nahas in Darfur by USA Company in 1977[1].

Previously, several studies concerning uranium and vanadium deposits in Sudanese phosphate deposits have been conducted in various areas [2, 3]. The results of these studies have not given detailed information on the presence of vanadium in the phosphate samples studied. However, a study published at 2014[5], gave detailed information concerning uranium recovery from Sudanese phosphate ores. This study was carried out in a laboratory scale to recover uranium from Uro area phosphate ore in the eastern part of Nuba Mountains in Sudan. Phosphate ore samples were collected, and analyzed for uranium and vanadium abundance. The results showed that the samples contain a significant concentration of vanadium with an average of 2793 ppm. The present study showed that Sudanese phosphate contains reasonable abundance of vanadium. The average vanadium concentration was found to reach an average of 3667 ppm in some samples.

2. MATERIALS AND METHODS
Previous Studies on Sudanese Phosphate Deposits
The phosphate deposits, which are the prime source of phosphate used in the manufacture of phosphate fertilizers and phosphoric acid, contain low concentrations of uranium in the fine grained apatite. This type of

deposit is considered to be an unconventional source of uranium; this offers the phosphate industry an attractive opportunity to recover uranium as a by-product of fertilizers and, therefore, has greatly renewed interest in the wet-process phosphoric acid as a significant source of uranium (IAEA, 1990; Becker, (1993) [6].In Sudan, there is a great need to obtain cheap and safe sources of phosphoric acid and phosphate fertilizers. The need to fertilizers increases annually with the increase of Sudan population and the global demand of grains. Brinkman (1986) discovered two types of phosphate deposits in Kurn and Uro areas in the center of eastern part of Nubba Mountains. Presently, phosphate ores from Kurn and Uro areas became the subject of intensive studies by several Investigators. The natural radionuclide content of phosphate has been documented by several works (Sam and Holm, 1995; Sam et al, 1999[7].Sam reported that Uro area phosphate ores generally have a high concentration of U, and he found that 238 U and its decay products are the principle contributors of radioactivity in these phosphate deposits, with activity concentrations ranging from 1225 to 13745 Bq/kg. Adam and Eltayeb investigated uranium abundance in Kurn and Uro areas; they found that uranium abundance in Uro phosphate is fife time higher than in Kurn phosphate (Adam and Eltayeb, 2009)[8]. Due to its significant concentration of uranium, we must show more interest to Uro phosphate.

1. Samples Preparation

The present work is focused to the center of the eastern part of the Nubba Mountains in the state of Kurdufan, between Abu Giubiha and El Rashad towns at the intersection of North east of the coordinate 11450north and 3122east. Rock phosphate samples collected from Uro and Kurn phosphate deposits located in the eastern part of Nubba Mountains, in southern Kurdfan State.

Sample were crushed and ground to 2mm size, to facilitate Uranium releasing and ending up in the leaching Solution .Sub-samples from bulk samples were taken using quartering technique which consists of piling the ore into conical heap , spreading this out into circles cakes , and dividing the cake into the quarters , taking opposite quarters . This process was repeated until suitable samples were collected. After collecting the samples that were taking the silver color, one gram of the sample was placed in the XRF device. The results were recorded on the results tables (Tables 1 and 2)

2. Results

Samples Analysis Method

Using in sample analysis XRF machine where were taken every one gram of powder sample and put it in the machine and calculate the concentration of each of the elements in the sample.

XRF Analysis Result

1. Kurn Sample

Table (1) Statistical Analysis Kurn Samples

Sample/ppm	Tb	Th	Tm	U	V	W	Y	Yb	Zr
1	0.3	0.4	0.6	205	1676	26.3	50.7	4.9	16
3	0.4	0.3	3.9	208.3	7106	1.9	195.8	18.8	24
4	0.3	1.1	0.5	131.7	1425	2	33.5	4.2	30
5	0.4	0.6	3	184.1	3453	2	170.7	27.5	32
6	1.0	0.6	3.9	128.1	2554	3.8	267.5	24.4	25
7	0.8	0.9	3.6	139.7	2713	3.1	235.6	26	24
8	0.6	0.7	2.2	184.9	5015	25.4	132.1	18	19
9	1.3	0.4	1.8	110.6	4895	1.9	130.4	12.3	18
10	1.2	0.3	1.7	110.5	4874	1.8	127.7	14	17
11	1.8	0.1	4.3	174.2	3614	3.9	231.9	32.8	10
12	1.7	0.4	4.8	188.8	1163	4.7	242.7	37.3	22
13	0.7	0.3	3.2	67.9	2093	1.2	211.9	21.9	7
14	0.3	0.4	0.4	90.1	211	1.2	30,7	2.5	16
15	0.1	0.3	0.2	56.3	253	1.1	25.4	1.7	33
16	0.3	0.3	0.4	22,6	181	19	40.4	2.7	44
17	0.2	0.2	2.6	43.0	4220	0.9	112.9	25.1	12
18	0.1	0.4	0.8	29.3	1975	0.9	31.3	7,8	13
19	0.2	0.1	0.7	20.8	1293	0.8	30.6	7.4	8

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20	0.3	0.4	2.1	46.2	4353	2.1	76.5	19.4	16
Average $\bar{x}$	**0.63**	**0.43**	**2.14**	**103.27**	**2793**	**5.47**	**125.17**	**16.25**	**20.32**
Standard Deviation σ	**0.53**	**0.25**	**1.51**	**63.98**	**1930**	**8.23**	**85.83**	**10.96**	**9.53**

The average Concentration of Uranium in the Kurn samples is 103.27 ± 64 ($\bar{x} \pm \sigma$) parts per million. This means that one ton of ore gives 103.27 ± 64 grams of uranium.

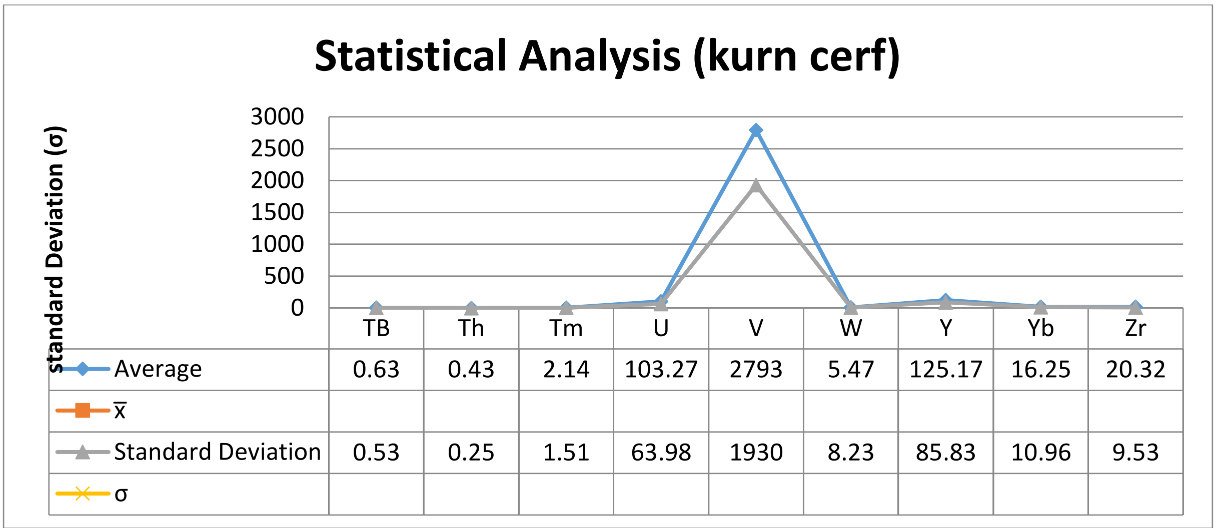

Fig.(1): Statistical Analysis Cerf (Kurn sample).

This study gives an average of 677 ppm and standard deviation of 597 ppm i.e. 677±597 (See the Table).

More interesting is the same one ton of the ore gives 2793± 1930 gram of vanadium (around 3 Kgm of Vanadium). About 80 percent of the vanadium now produced is used as ferrovanadium or as a steel additive. Vanadium foil is used as a bonding agent when cladding titanium to steel. Vanadium pent oxide is used in ceramics and as a catalyst. Vanadium is also used to produce a superconductive magnet with a field of 175,000 gauss

2. URO Samples

Table(2): Statistical Analysis Uro Samples

Sample/ppm	Tb	Th	Tm	U	V	W	Y	Yb	Zr
21	-	0.5	6.9	1101.3	4482	1.4	271.5	60	17
22	0.2	0.1	3.7	1128	4674	1	119.1	36.16	7
24	0.1	0.1	1.7	1128	4801	0.5	64.1	19.5	8
25	0.2	0.4	0.1	5.4	137	0.9	15.1	0.9	21
26	0.9	1.1	0.4	11.1	11.4	0.5	58.7	2.5	20
28	0.6	0.5	2.9	1166	3158	1.5	142.2	27.5	16
29	0.5	0.3	2.7	1183	4568	1.7	121	26.1	24
31	0.2	0.1	8	1193	5735	2.6	245.9	86.3	10
33	0.5	0.7	2.8	1171	4773	2.6	126.6	27.1	24
35	0.5	0.3	3.9	1156	1837	2.5	162.8	40.7	13
36	0.5	1.4	1.2	1149	6740	16.2	61.3	11.8	39
38	2.2	2.9	1.6	1160	3458	1.4	102.6	16.1	20
39	0.3	1.7	54	1154	5161	0.9	75.7	22.7	12
40	0.7	1.3	0.8	1086	1809	0.7	51.2	7	52
Average $\bar{x}$	**1.05**			**985.13**	**3667.45**				
Standard Deviation σ	**1.87**			**414.90**	**2035.8**				

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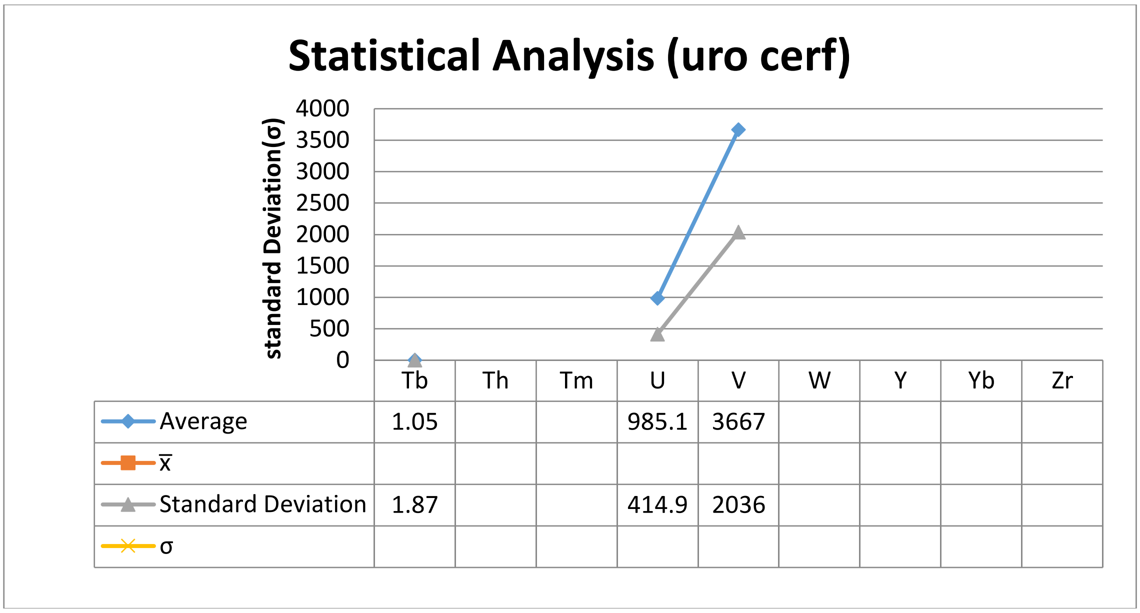

Fig.(2): Statistical Analysis Cerf (Uro sample).

Together with the reasonable concentration of uranium in the present study samples, a very high concentration of vanadium was found in both areas. The vanadium concentration is as high as 7,000 ppm in some samples of the Kurn area with an average of 2793 ppm as shown in Table 1. While the average vanadium concentration at Uro samples is 3667 ppm (Table 2). These concentrations gave a good reason to develop a detailed study on separation of vanadium from the phosphate deposits to make use of the vanadium as an economic source. Vanadium was discovered at 1805 by Del Rio[9] .It was not until 1830, that Sefstrom rediscovered the element and named it after the Scandinavian Goddess Vanadis, due to its attractive multicolored compounds. However it was not until 1867, that Roscoe reduced the chloride with hydrogen to isolate the first sample of vanadium. It took another 60 years before vanadium was produced with purities as high as 99.3 to 99.8% ·Vanadium is a ductile and malleable transition metal. It is harder than most metals and steels and is the most used alloy to strengthen steels. More than 90% of the Vanadium is used in high strength low alloy steel and carbon steel .Average value 3667.45ppm, while the Kurn area focus much lower, Average value 2793 ppm and this suggests that the deposits of vanadium of Uro region is higher than Kurn[9].

Statistical Analysis of Results

The twenty samples taken from Kurn Area gave an average ppm of 2793 with a standard deviation of 1930, while the samples taken from Uro Area gave an average ppm of 3667 with a standard deviation of 2035. These results show that the concentration of vanadium in Uro is much higher than the Kurn area. The concentration of vanadium found in rock samples extracted from the Uro area is much higher than vanadium concentration in the samples extracted from the Kurn region.

1. Vanadium Prices in The International Market:

According to Ryan's Notes, U.S. ferrovanadium (FeV) prices ranged from $13.750 to $14.281 per pound of vanadium content in January 2013, compared with $12.964 to $14.000 in December 2012. European FeV prices ranged from $30.813 to $31.813 per kilogram in January, compared with $27.000 to $28.000 in December.

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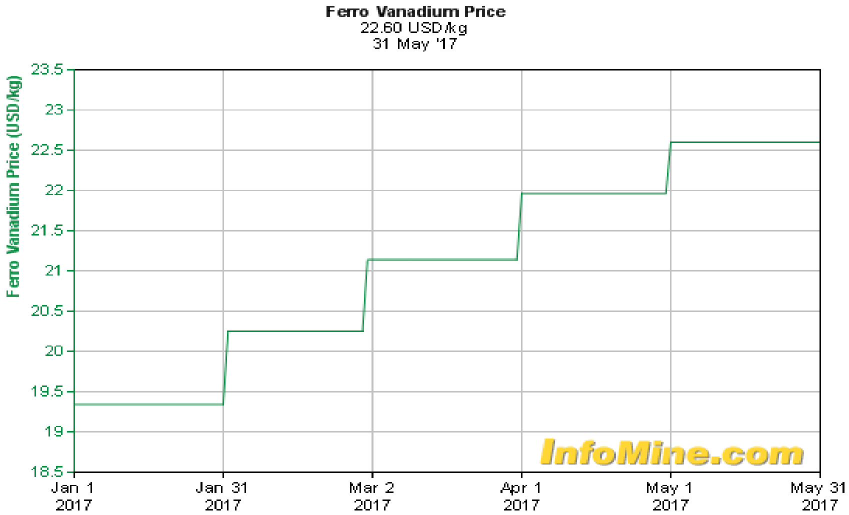

Fig.(3): Vanadium prices, 2017

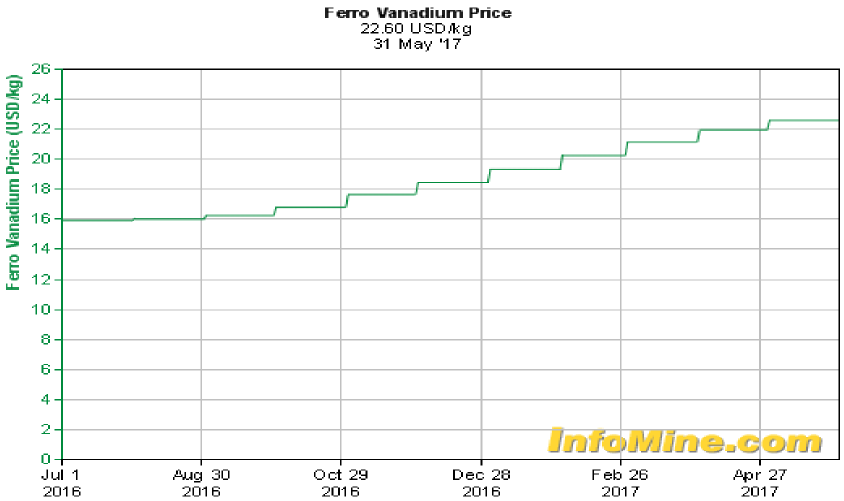

Fig. (4): Vanadium prices, 2016:

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Fig. (5): Vanadium price from 2005 to 2017

3. DISCUSSION

The average Concentration of Uranium in the Kurn samples is 103.27 ± 64 ($\bar{x} \pm \sigma$) parts per million. This means that one ton of ore gives 103.27 ± 64 grams of uranium. This study gives an average of 677 ppm and standard deviation of 597 ppm i.e. 677±597 (See the attached Table). It is very important to note that the concentration of th increase when that U decrease. This agrees with decay law where U decay to Th. More interesting is the same one ton of the ore gives 2793± 1930 gram of vanadium (around 3 Kg of Vanadium).About 80 percent of the vanadium now produced is used as ferrovanadium or as a steel additive. Vanadium foil is used as a bonding agent when cladding titanium to steel. Vanadium pent oxide is used in ceramics and as a catalyst. Vanadium is also used to produce a superconductive magnet with a field of 175,000 gauss. It is very important to note that table (1) for Kurn sample the higher concentration of U and V are in the same sample (see sample 3). The lower V and U are proportional to each other. The same proportionality is observed in table (2) for Uro area. I.e. the concentration of V and U are proportional to each other in general. This may be related to the fact that these elements are where famed in igneous rocks which are assumed to be formed from molten magma. In this molten state heavy elements reside at the bottom with high concentration, while their concentration decreases with distant. Thus are expect higher concentration samples to be collected from deep areas

4. CONCLUSION

It could be seen that one ton of the ore gives 2793± 1930 gram of vanadium (around 3 Kgm of Vanadium per one ton of ore).About 80 percent of the vanadium now produced is used as ferrovanadium or as a steel additive. Vanadium foil is used as a bonding agent when cladding titanium to steel. Vanadium pent oxide is used in ceramics and as a catalyst. Vanadium is also used to produce a superconductive magnet with a field of 175,000 gauss. Surface concentration of secondary uranium in granites, although unlikely to from large deposits, have not been evaluated in depth and warrant further exploration. These occurrences are at Nubba mountains Kurn and Uro. It is clear from this report that there is considerable potential for the development of deposits of vanadium within the sedimentary cover of this region of the Sudan Republic. Also, on the basis of work carried out to date it becomes apparent that the delineation of blind ore bodies within the cover rocks will entail extensive exploration in depth and it is possible, even at this stage, to foresee exploration budgets in the order of US $ 500,000 to 1,000,000 being necessary to fully evaluate the anomalous areas located. Exploration within central Sudan in not easy and severe logistic problems are entailed which are aggravated by difficulties in obtaining water and fuel. Also, there are possible difficulties in obtaining appropriate drilling equipment and operators locally. While exploration of the hard-rock occurrences in granites could proceed, in the short-term a considerable project appraisal effort has to be undertaken prior to embarking on the long and costly process of exploring the sedimentary cover. This project appraisal would entail a visit to Khartoum to assess the local availability of suitable drilling equipment and would allow a budget to be established for an exploration programmed based on known local factors.

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