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Radioactive Disequilibrium Studies in Uranium Series of Core Samples of Koppunuru Area, Guntur District, Andhra Pradesh, India

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Abstract

Disequilibrium studies were attempted on mineralised core samples (n=870) from Koppunuru uranium deposit located in south-western part of Palnad sub-basin, Guntur district, Andhra Pradesh, India. The area exposes Banganapalle quartzites unconformably deposited over altered biotite granite (basement). Uranium mineralisation in Koppunuru deposit is hosted by Banganapalle quartzites well above the unconformity, and grit/basement granite close to the unconformity contact. For disequilibrium studies, the core samples were broadly divided in two groups, (a) quartzite hosted (above unconformity) and (b) basement granite hosted mineralisation (below unconformity). Average disequilibrium factor of 41% has been recorded in favour of parent uranium in both types of core samples. It shows significant enrichment of uranium in the system as evident from 41% of disequilibrium in favour of parent uranium. This is probably due to significant migration of some of the daughter radio nuclides due to dissolution of minerals by groundwater action. Besides, the escape of radioactive radon might have accentuated the disequilibrium factor thus increasing the grade of uranium mineralization. The presence of fractures and faults in the study area are the probable conduits for radon migration/escape. Linear regression coefficient between uranium and radium is 0.98 indicates invariability of disequilibrium irrespective of grade.

Keywords: Uranium; Disequilibrium factor; Beta-gamma method; Gamma ray spectrometry; Guntur district; Andhra Pradesh

Introduction

Linkage between economic growth of any country and energy requirement is well known, and hence, sustainable energy resources are essential. During the past three decades the world was able to cope with an increasing energy demand by relying more on fossil fuel [1-3]. However, the progressively dwindling reserves of fossil fuel and a deep-rooted concern about global warming, arising out of CO_2 emission due to the excessive use of fossil fuel, have now developed a growing interest in nuclear energy as an alternative green source [4,5]. Uranium is one of the main nuclear fuels, continuous supply of which is needed for sustainable development in the energy field. In India, an extensive exploration programme is being carried out in different geological domains to establish new uranium resources and reserves to overcome the demand and supply gap in nuclear energy sector. The uranium series disequilibrium in radioactive ore poses a critical problem for proper assessment of the resource in most of the cases. However, it is observed that the magnitude and frequency of radioactive disequilibria is generally ignored which leads to underestimation or overestimation of ore reserve [6,7]. Thus, to overcome uranium ore deposit evaluation related constraints, the disequilibrium studies are significant both in field and laboratory counting measurements.

In the uranium series, the system is considered to be in radioactive equilibrium when all the daughter products decay at the same rate in which they are produced from the parent isotope in an ideally closed system [6,8,9]. Thus, at radioactive equilibrium, each of the daughter products would be present in a constant proportion to the parent isotope. However, such equilibrium is rarely observed in uranium ore bodies [7,9]. Various studies have been undertaken on the nature and significance of disequilibrium conditions in uraniferous deposits [10], which have indicated that different geologic and physicochemical processes influence the system. The addition or removal of any isotope in the disintegration series in a radioactive mineral causes disequilibrium in the proportions of the parent isotope to its daughter products [9]. The present paper deals with the evaluation of disequilibrium pattern in unconformity proximal and fracture controlled types of uranium mineralisation in Koppunuru area, Guntur district, Andhra Pradesh, India using beta-gamma and gamma-ray spectrometry techniques on mineralised borehole core samples.

Geological Setting

Koppunuru area is located in the south-western part of the Neoproterozoic Palnad Sub-basin, where Kurnool sediments are deposited unconformably over the Archaean to Palaeoproterozoic basement granite and gneisses [11,12]. Basement granites are exposed as an inlier over an area of 5 km x 2.5 km to the south-east of Koppunuru, and along the up-thrown block of regional WNW-ESE trending fault to the south of Koppunuru (Figure 1). These are dissected by a number of ENE–WSW, NE–SW, NW–SE and a few N–S trending lineaments represented by dolerite dykes, fractures and faults [13]. The Kurnool sediments are mainly represented by Banganapalle, Narji and Paniam formations comprising quartzites, shales and limestones. The Banganapalle Formation (10-173m thick), the oldest sedimentary lithounit in the study area, and comprises quartzite and intercalated grey shale sequence with basal conglomerate/grit [12].

Proterozoic unconformity-related uranium deposit in Koppunuru and adjoining areas is predominantly (~85%) hosted by Banganapalle quartzite and grit. At places the mineralisation also transgresses below

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the unconformity contact in basement granites along the fracture planes [7,14-19]. It is observed that the mineralisation follows a predominant N-S to NNE–SSW trend sympathetic to faults and fractures in the area. Pitchblende and coffinite are identified as primary uranium ore minerals in Koppunuru deposit, while uranophane, phosphuranylite, metazeunerite and U-Ti complex occur as secondary uranium minerals [15,17].

Sampling and Analytical Techniques

A total of 870 mineralised core samples from 34 boreholes of Koppunuru area have been collected for disequilibrium studies, which includes 620 quartzite/grit and 250 granite samples. Drilling was done using different capacity mechanical coring rigs (Rock Drill-30, Drill Max-400 and Trolley mounted Rock Drill-300). Uranium mineralisation has been intercepted along the studied boreholes at different depths ranging from 26.0 m to 170.0 m. Different mineralised bands show grade and thickness ranging from 0.01% to 0.322% eU_3O_8 and 0.6 m to 7.0 m respectively. Details of mineralized intercepts, lithounit, depth of unconformity, and number of samples collected is shown in Table 1. The mineralised core samples were crushed to -200 mesh to homogenize. 50 g and 140 g of sample were taken after conning and quartering for determination of U_3O_8 (%) by β/γ method, and equivalent U_3O_8 (% eU_3O_8), radium equivalent U_3O_8 (%Ra eU_3O_8), % ThO_2 and % K using High Energy Gamma Ray Spectrometry (HEGS) respectively [6,20]. The representative samples were transferred to

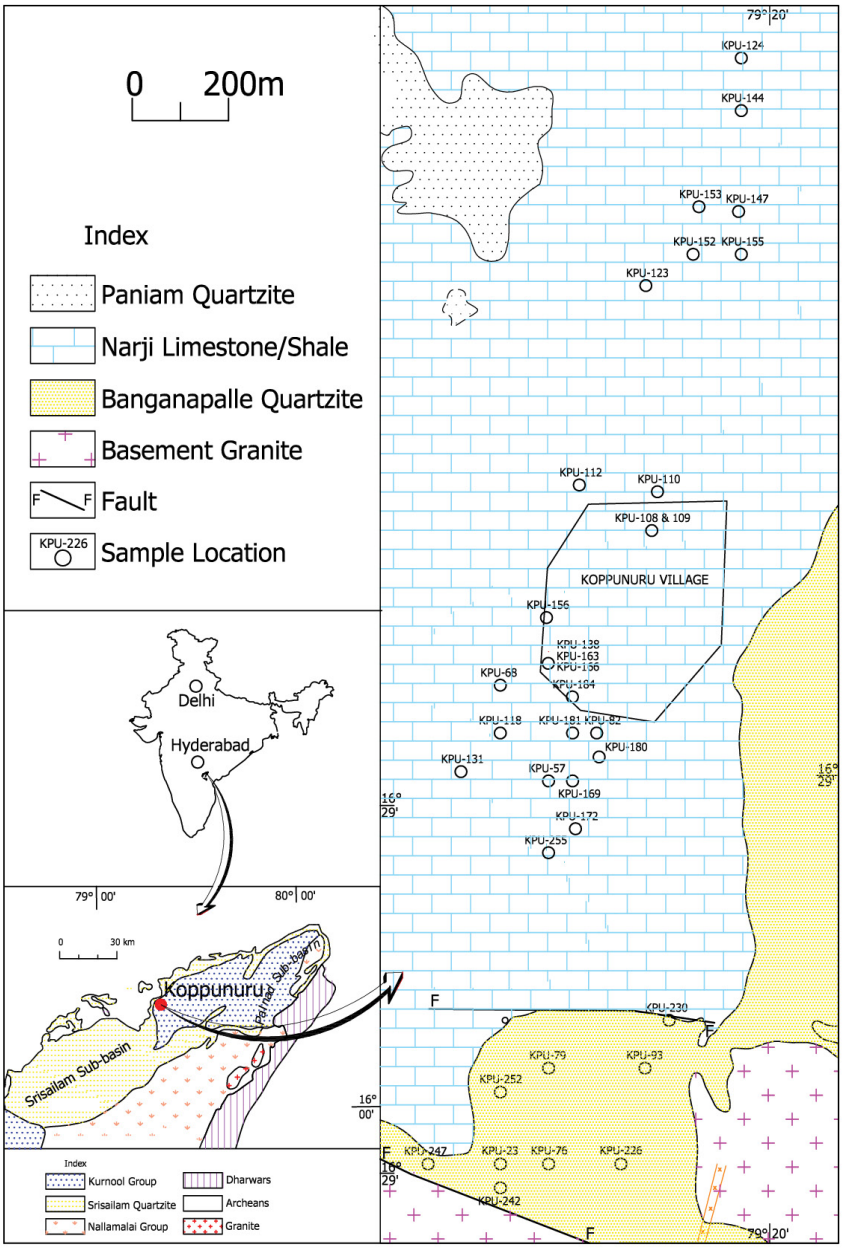

Figure 1: Geological map of Koppunuru area, Guntur district, Andhra Pradesh along with studied borehole locations.

S.No	BH NO.	Mineralised zone		Thickness x Ave.Grade (%eU_3O_8)	Rock Type	Depth of unconformity (m)	n
		from (m)	to (m)				
1	**KPU/23**	101.25	101.85	0.60 m of 0.040	Gritty Quartzite	**107**	**8**
		104.75	106.45	1.70 m of 0.090	Gritty Quartzite		
2	**KPU/57**	106.21	107.21	1.00 m of 0.319	Granite	**104.3**	**9**
3	**KPU/68**	53.15	53.75	0.60 m of 0.023	Gritty Quartzite	**56**	**3**
		55.75	56.75	1.00 m of 0.031	Granite		**2**
4	**KPU/76**	63.15	64.35	1.20 m of 0.088	Gritty Quartzite	**65.2**	**7**
5	**KPU/79**	54.88	57.95	3.07 m of 0.130	Gritty Quartzite	**58.5**	**23**
		60.05	61.27	1.22 m of 0.130	Granite		**10**
6	**KPU/82**	160	161.4	1.40 m of 0.041	Gritty Quartzite	**162**	**3**
		163.8	164.8	1.00 m of 0.016	Granite		**2**
7	**KPU/93**	104.65	108.45	3.80 m of 0.130	Quartzite/Shale	**119**	**11**
		114.95	116.35	1.40 m of 0.017	Gritty Quartzite		
8	**KPU/108**	156.65	157.65	1.00 m of 0.043	Gritty Quartzite	**161**	**5**
		158.95	159.25	0.30 m of 0.011	Gritty Quartzite		
9	**KPU/110**	140.85	142.05	1.20 m of 0.021	Granite	**140.7**	**14**
		148.63	149.79	1.16 m of 0.031	Granite		
10	**KPU/112**	165.25	168.85	3.60 m of 0.051	Quartzite/Shale	**169.45**	**28**
					Gritty Quartzite		
11	**KPU/118**	140.85	142.45	1.60 m of 0.100	Gritty Quartzite	**145.15**	**22**
		145	146	1.00 m of 0.019	Granite		**9**
12	**KPU/123**	159.1	163.1	4.00 m of 0.028	Gritty Quartzite	**167.4**	**17**
13	**KPU/124**	125.96	127.1	1.14 m of 0.224	Gritty Quartzite	**127.8**	**16**
		129.9	131.38	1.48 m of 0.020	Granite		**24**
14	**KPU/131**	147.24	148.43	1.19 m of 0.017	Gritty Quartzite	**149.6**	**23**
		148.72	150.03	1.31 m of 0.016	Granite		**4**
15	**KPU/138**	141.64	147.08	5.44 m of 0.322	Gritty Quartzite	**156.4**	**93**
		147.9	152.81	4.91 m of 0.098	Gritty Quartzite		
		154.14	155.29	1.15 m of 0.025	Gritty Quartzite		
		155.4	158.11	2.67 m of 0.020	Granite		**20**
		160.38	161.65	1.27 m of 0.018	Granite		
16	**KPU/144**	128.38	130.04	1.66 m of 0.175	Gritty Quartzite	**134.15**	**12**
		135.22	136.26	1.04 m of 0.024	Granite		**38**
		139.04	140.27	1.23 m of 0.021	Granite		
		149.15	150.61	1.46 m of 0.032	Granite		
17	**KPU/147**	128.05	129.25	1.20 m of 0.090	Gritty Quartzite	**142.8**	**3**
		143.59	144.88	1.29 m of 0.022	Granite		**13**
18	**KPU/152**	135.95	138.05	2.10 m of 0.270	Gritty Quartzite	**155.7**	**21**
		155.8	156.4	0.60 m of 0.026	Granite		**10**
		160.75	161.8	1.05 m of 0.031	Granite		
19	**KPU/153**	113	114.07	1.07 m of 0.019	Gritty Quartzite	**151.2**	**13**
		132.75	133.75	1.00 m of 0.073	Gritty Quartzite		
20	**KPU/155**	121.5	122.7	1.30 m of 0.074	Gritty Quartzite	**138.5**	**6**
21	**KPU/156**	154.4	155.75	1.35 m of 0.017	Gritty Quartzite	**162.35**	**16**
22	**KPU/163**	138.31	139.34	1.03 m of 0.067	Gritty Quartzite	**143.8**	**28**
		142.15	143.66	1.51 m of 0.099	Gritty Quartzite		
		154.86	157	2.14 m of 0.152	Granite		**37**
23	**KPU/166**	146.22	147.42	1.20 m of 0.027	Gritty Quartzite	**156.9**	**22**
		155.05	156.85	1.80 m of 0.043	Gritty Quartzite		
		156.9	159.3	2.40 m of 0.027	Granite		**20**
24	**KPU/169**	90.45	91.65	1.20 m of 0.048	Gritty Quartzite	**98.8**	**12**
25	**KPU/172**	40.03	41.11	1.08 m of 0.081	Quartzite	**84.3**	**20**
		80.15	81.85	1.70 m of 0.038	Gritty Quartzite		
		86.65	86.55	0.90 m of 0.012	Granite		**6**
26	**KPU/180**	37.41	39.88	2.47 m of 0.139	Quartzite	**91**	**28**
		79.38	80.42	1.04 m of 0.101	Gritty Quartzite		
		81.05	82.25	1.20 m of 0.067	Gritty Quartzite		

27	**KPU/181**	106.55	108.55	1.20 m of 0.065	Gritty Quartzite	**108.8**	**16**
		108.9	109.2	0.30 m of 0.200	Granite		**1**
28	**KPU/184**	115.65	116.67	1.02 m of 0.018	Gritty Shale	**128.8**	**52**
		121.55	128.55	7.00 m of 0.038	Gritty Quartzite		
		139.55	141.45	1.90 m of 0.025	Granite		**14**
29	**KPU/226**	38.35	39.65	1.30 m of 0.031	Gritty Quartzite/Shale	**40.65**	**7**
30	**KPU/230**	25.45	27.35	1.90 m of 0.057	Conglomerate	**27.9**	**10**
31	**KPU/242**	79.05	80.95	1.90 m of 0.213	Shale/Quartzite	**87.7**	**13**
32	**KPU/247**	86.48	88.95	2.47 m of 0.105	Quartzite	**111.55**	**45**
		104.2	106.6	2.50 m of 0.017	Grit/Conglomerate		
		109.15	110.45	1.30 m of 0.020	Grit/Conglomerate		
		112.15	112.75	0.60 m of 0.016	Granite		**10**
		119	119.6	0.60 m of 0.023	Granite		
33	**KPU/252**	69.1	70.6	1.60 m of 0.020	Quartzite	**73.4**	**9**
		73.5	75.7	2.20 m of 0.018	Granite		**7**
		84.3	85.3	1.00 m of 0.011	Granite		
34	**KPU/255**	88.08	89.19	1.11 m of 0.039	Quartzite	**100.9**	**28**
		94.35	96.25	1.90 m of 0.031	Conglomerate		
						Total	**870**

Table 1: Details of mineralised zones in boreholes and host rock of Koppunuru area, Guntur district, Andhra Pradesh.

airtight plastic containers and kept for about a month for attainment of radioactive equilibrium between radon daughters and parent radium in the uranium series [21,22]. Besides, U_3O_8 contents in the samples were also estimated by simultaneous measurement of total beta and total gamma radiations using a LND 73201 beta tube, and 1.75" x 2" NaI(Tl) scintillation detector, respectively in the samples [23,24].

Estimation of uranium

The concentration of U_3O_8 in the sample was estimated by simultaneous measurement of total beta and total gamma radiations by beta gamma method using equation:

$$U_3O_8 = (1+C)U_\beta - CU_\gamma \quad [25] \quad (1)$$

Where $U_{\beta=\beta}$ activity of uranium in sample.

$U_{\gamma=\gamma}$ activity of uranium in sample.

C=ratio of Ra_β to U_β in standard.

The detection limit is 90 ppm with ± 10% error. For accuracy an IAEA reference standard RGU-1 (U_3O_8 value 460 ppm and $Ra(eU_3O_8)$ value 470 ppm) was also analysed (n=5). The U_3O_8 value obtained for RGU-1 by this method was 453 ± 24 ppm.

Estimation of Ra (eU_3O_8), ThO_2 and K

$Ra(eU_3O_8)$, ThO_2 and K concentrations in the samples were estimated by using gamma ray spectrometry. A 5" x 4" NaI(Tl) scintillation detector was used for the analysis. The detector was coupled to a dMCA-pro-digital- Multi Channel Analyser (Terjet, Germany). The dMCA directly digitizes signals from the radiation detector and stores them in the format desired by the inbuilt software (winTMCA32). For the estimation of $Ra(eU_3O_8)$, the 1.76 MeV gamma ray energy was measured from the Bi-214 as the daughter of radium series always remains in equilibrium with radium. The estimation of ThO_2 was done by measuring the 2.62 MeV gamma ray energy from Tl-208 and the 1.46 MeV of gamma ray energy was measured for the estimation of % K. Prior to this, energy calibration was done using standard gamma ray sources ^{137}Cs 662 KeV and ^{60}Co 1173KeV and 1332 KeV energies. The stripping and sensitivity factors were calculated using standard reference material RGU-1, RGTh-1 and RGK-1supplied by IAEA, Vienna. An In-house (developed at Atomic Minerals Directorate for Exploration and Research, Hyderabad) equilibrium U_3O_8 standard was also used for sensitivity calculations. The samples and standards were taken in the plastic containers of the same volume and size to maintain a same counting geometry to minimize the geometrical error. The containers were sealed carefully to avoid the escape of radon gas from the samples. The counting of samples was done in a Low Background room which is ~4 ft below the ground level and walls of the room are made of quartz, with a thickness of 0.9 m. The energy spectra from each sample were obtained by placing the sample on the top of detector.

The $Ra(eU_3O_8)$ concentration was calculated by dividing the net peak area of the characteristic gamma ray energy of 1.76 MeV to the sensitivity of radium [26]. Sensitivity of $Ra(eU_3O_8)$ with a counting time of 200 s is 6.5 counts/ppm for 140 g of sample weight and detection limit is 2 ppm (error <10%). ThO_2 concentration was calculated by dividing the net peak area of the characteristic gamma ray energy of 2.62 MeV to the sensitivity of thorium and similarly the concentration of % K is calculated by dividing the net peak area of characteristic gamma ray energy of 1.46 MeV to the sensitivity of potassium. Sensitivity of ThO_2 with a counting time of 200 s is 2.1 counts/ppm for 140 g of sample weight and detection limit is 5 ppm (error <10%). The net peak area of gamma ray was obtained by subtracting background counts and stripping of the higher energy contribution.

Results and Discussion

The uranium concentration, $Ra(eU_3O_8)$ concentration of 870 core samples from 34 boreholes of Koppunuru deposit with disequilibrium factor (DF), number of samples of both above and below unconformity, mineralised depth ranges, and minimum, maximum and average values of U_3O_8, $Ra(eU_3O_8)$ and ThO_2 of the studied core samples are given in Table 2.

The linear regression equation between radium concentration and uranium concentration has been found from the regression plot:

$$Y(U_3O_8) = 1.384\,X\,(Ra(eU_3O_8)) + 5.862 \text{ with } R^2 = 0.976 \quad (2)$$

The linear regression plot of studied samples has indicated a correlation coefficient of 0.976 (Figure 2). This plot indicates the association of daughter product with significant enrichment of parent

S. No.	BH No.	No of sample	U_3O_8 (ppm)			$Ra(eU_3O_8)$ ppm			Av. ThO_2	DF	No. of samples	
		(n)	Min	Max	Av.	Min.	Max.	Av.	(ppm)		Above u/c	below u/c
1	**KPU/23**	**8**	107	2875	**774**	73	2028	**624**	**21**	**1.17**	8	0
2	**KPU/57**	**9**	91	1344	**293**	57	536	**158**	**19**	**1.64**	0	9
3	**KPU/68**	**5**	139	420	**255**	84	372	**181**	**26**	**1.47**	3	2
4	**KPU/76**	**7**	210	3600	**1333**	132	2270	**830**	**57**	**1.47**	7	0
5	**KPU/79**	**33**	122	13529	**1749**	91	8185	**1236**	**26**	**1.32**	23	10
6	**KPU/82**	**5**	140	521	**285**	104	413	**221**	**17**	**1.34**	3	2
7	**KPU/93**	**11**	99	715	**330**	83	592	**267**	**5**	**1.27**	11	0
8	**KPU/108**	**5**	94	448	**203**	69	294	**139**	**21**	**1.44**	5	0
9	**KPU/110**	**14**	113	1848	**488**	111	996	**303**	**32**	**1.37**	0	14
10	**KPU/112**	**28**	95	2730	**516**	64	2483	**375**	**22**	**1.35**	28	0
11	**KPU/118**	**31**	95	1099	**291**	75	927	**251**	**20**	**1.28**	22	9
12	**KPU/123**	**17**	90	1247	**352**	59	941	**265**	**34**	**1.4**	17	0
13	**KPU/124**	**40**	92	7040	**656**	55	6034	**530**	**22**	**1.29**	16	24
14	**KPU/131**	**27**	90	1095	**207**	68	820	**163**	**26**	**1.28**	23	4
15	**KPU/138**	**113**	93	8933	**1489**	80	7689	**1215**	**25**	**1.26**	93	20
16	**KPU/144**	**50**	105	7298	**724**	78	5081	**533**	**63**	**1.33**	12	38
17	**KPU/147**	**16**	101	9851	**1179**	96	6881	**795**	**78**	**1.33**	3	13
18	**KPU/152**	**31**	111	2104	**422**	98	1541	**335**	**12**	**1.23**	21	10
19	**KPU/153**	**13**	123	4264	**621**	97	3104	**470**	**6**	**1.27**	13	0
20	**KPU/155**	**6**	117	3055	**1154**	85	1908	**781**	**12**	**1.37**	6	0
21	**KPU/156**	**16**	122	559	**226**	94	302	**160**	**11**	**1.44**	16	0
22	**KPU/163**	**65**	91	7863	**841**	72	4635	**594**	**27**	**1.33**	28	37
23	**KPU/166**	**42**	95	6700	**558**	61	5098	**402**	**27**	**1.44**	22	20
24	**KPU/169**	**12**	229	3165	**1048**	187	2188	**712**	**18**	**1.36**	12	0
25	**KPU/172**	**26**	102	3241	**802**	81	2297	**566**	**9**	**1.4**	20	6
26	**KPU/180**	**28**	110	13851	**2004**	28	6885	**1333**	**15**	**1.88**	28	0
27	**KPU/181**	**17**	105	4973	**1506**	15	3491	**1170**	**33**	**1.62**	16	1
28	**KPU/184**	**66**	114	6066	**509**	63	2240	**307**	**15**	**1.5**	52	14
29	**KPU/226**	**7**	95	681	**316**	100	373	**224**	**13**	**1.32**	7	0
30	**KPU/230**	**10**	118	3623	**632**	84	1968	**507**	**8**	**1.43**	10	0
31	**KPU/242**	**13**	101	9558	**3071**	86	5652	**2065**	**6**	**1.29**	13	0
32	**KPU/247**	**55**	115	3923	**544**	82	2909	**394**	**16**	**1.59**	45	10
33	**KPU/252**	**16**	90	953	**259**	46	358	**129**	**32**	**2**	9	7
34	**KPU/255**	**28**	90	907	**358**	74	679	**245**	**28**	**1.46**	28	0
	Total	**870**										
	Average		112	4120	**765**	80	2711	**544**	**24**	**1.41**	**620**	**250**

Table 2: Details of U_3O_8, $Ra(eU_3O_8)$ and disequilibrium factor (DF) of borehole core samples of Koppunuru area, Guntur district, Andhra Pradesh.

and good correlation among them. The average ThO_2 concentrations of these borehole core samples range from 5 ppm to 78 ppm. The split details of number of boreholes, the concentration ratio of ThO_2/ U_3O_8 in different boreholes is shown in Figure 3. This histogram is showing statistics of the distribution pattern of boreholes in different ratio ranges of ThO_2/ U_3O_8 viz. maximum 10 boreholes fall between 0.01-0.02 range while only 1 borehole falls under 0.13-0.14 range category.

The disequilibrium factor (DF) in the sample is calculated by the following formula

$$DF = U_3O_8 \text{ in the sample} / Ra(eU_3O_8) \text{ in the sample} \quad (3)$$

The disequilibrium is towards the parent uranium if the value of DF is more than one (DF>1). This is favourable for the prospector as it shows enrichment of uranium resulting in positive corrections in the final ore reserve estimation based on total gamma ray logging data. In contrast, if the value of DF is less than one (DF<1), then disequilibrium

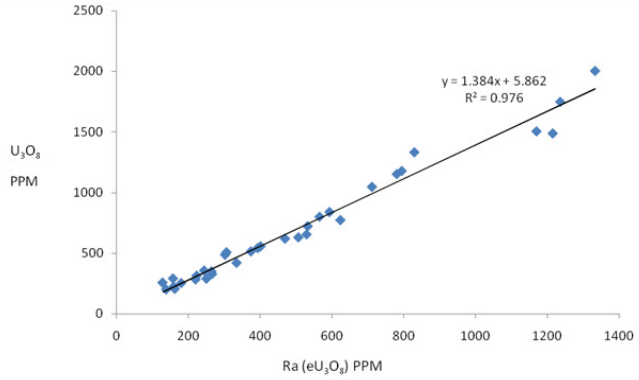

Figure 2: Linear regression plot between Ra (eU_3O_8) and U_3O_8 of borehole core samples.

is towards the daughter radium and is a non-desirable condition for uranium prospecting. It signifies partial removal of uranium from the system leading to a lowering of final ore reserve estimates based on total gamma ray logging data. All the boreholes have shown average DF significantly greater than 1 and the disequilibrium factors for studied core samples are listed in Table 2, which shows an average value of 1.41. This suggests enrichment of uranium either due to remobilization and deposition of uranium at the present locale or leaching of daughter products of the uranium series leading to an increase in concentration of parent uranium. These features are further supported by the presence of fractures, faults, felsic and mafic intrusive signifying pre- and post-depositional reactivation in the area providing a hydrothermal gradient for remobilization [17,19]. In addition, the presence of higher hydrouranium content (<10 ppb) away from the ore deposit suggests a possible role of groundwater on radioelement migration and fixation at suitable locales [27].

The studied mineralised core samples are broadly classified in two groups i.e. granite (below uniformity) and cover rock of Banganapalle quartzite/grit (above the unconformity). The disequilibrium factor is separately calculated for both types of samples. Average disequilibrium factor for the granite and quartzite/grit samples is 1.41 (Table 3) and 1.40 (Table 4) respectively. Thus, the study distinctly indicates close similarity in disequilibrium factor for both groups of samples, irrespective of the different lithic compositions and geologic position.

Impact on the ore reserve estimation

The presence of disequilibrium in uranium series between parent and daughter Radium-226 implies that ore grades of mineralised zones demarcated based on total gamma ray logging results needs to be corrected. Usage of Disequilibrium factor will lead to an upward revision in the total estimated resources. The disequilibrium correction factor calculated for core samples of different boreholes ranges from 1.29 to 1.47 of eU_3O_8 (Table 5).

Conclusion

The disequilibrium studies on the mineralised samples from the boreholes of the Koppunuru deposit has indicated:

1. Presence of strong disequilibrium in favour of parent uranium, with average value of 1.41.

2. DF is nearly same in the mineralisation hosted by both basement granites and Banganapalle quartzite.

3. Presence of disequilibrium in the mineralised zone implies an

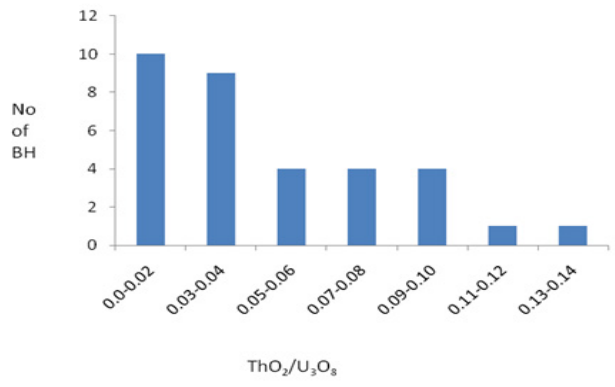

Figure 3: Histogram showing ThO_2/U_3O_8 ranges of borehole core samples of Koppunuru area, Guntur district.

S. No.	BH. No.	No. of samples	DF
1	KPU/57	9	1.64
2	KPU/68	2	1.06
3	KPU/79	10	1.2
4	KPU/82	2	1.57
5	KPU/110	14	1.37
6	KPU/118	9	1.36
7	KPU/124	24	1.29
8	KPU/131	4	1.28
9	KPU/138	20	1.46
10	KPU/144	38	1.32
11	KPU/147	13	1.33
12	KPU/152	10	1.36
13	KPU/163	37	1.34
14	KPU/166	20	1.49
15	KPU/172	6	1.62
16	KPU/181	1	1.03
17	KPU/184	14	1.45
18	KPU/247	10	1.86
19	KPU/252	7	1.85
		Total=250	**Average=1.41**

Table 3: Disequilibrium factor of Granites borehole core samples (below unconfirmity), Koppunuru area, Guntur District, Andhra Pradesh.

S. No.	BH. No.	No. of samples	DF
1	KPU/23	8	1.17
2	KPU/68	3	1.75
3	KPU/76	7	1.47
4	KPU/79	23	1.38
5	KPU/82	3	1.18
6	KPU/93	11	1.27
7	KPU/108	5	1.44
8	KPU/112	28	1.35
9	KPU/118	22	1.25
10	KPU/123	17	1.4
11	KPU/124	16	1.3
12	KPU/131	23	1.28
13	KPU/138	93	1.24
14	KPU/144	12	1.36
15	KPU/147	3	1.36
16	KPU/152	21	1.2
17	KPU/153	13	1.27
18	KPU/255	6	1.37
19	KPU/256	16	1.44
20	KPU/163	28	1.3
21	KPU/166	22	1.39
22	KPU/169	12	1.36
23	KPU/172	20	1.33
24	KPU/180	28	1.88
25	KPU/181	16	1.66
26	KPU/184	52	1.51
27	KPU/226	7	1.32
28	KPU/230	10	1.43
29	KPU/242	13	1.29
30	KPU/247	45	1.51
31	KPU/252	9	1.79
32	KPU/255	28	1.46
		Total=620	**Average=1.40**

Table 4: Disequilibrium factor of Banganapalle quartzite /grit borehole core samples (above unconformity), Koppunuru area, Guntur district, Andhra Pradesh.

Range eU_3O_8 (ppm)	No of Samples	Avg. U_3O_8 (ppm)	DF=U/Ra
90-200	412	162	1.47
201-400	204	332	1.29
401-600	49	613	1.32
601-800	33	953	1.39
801-1000	20	1264	1.45
1001-1500	53	1711	1.4
1501-2000	28	2275	1.33
2001-2500	21	3067	1.42
2501-3000	9	3480	1.3
3001-4000	18	4572	1.35
4001-8500	22	7817	1.39

Table 5: Disequilibrium factor core samples with different eU_3O_8 ranges of Koppunuru area, Guntur district, Andhra Pradesh.

upward correction in the ore grades, calculated based on total gamma log, by a factor of 1.41. Thus, an increase in grade and tonnage of the total estimated resources in Koppunuru deposit is indicated.

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