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Delineation of Target Zones for Detailed Uranium Exploration Using Secondary Dispersion Haloes (Pedogeochemical) as a Tool in the NNW Parts of Srisailam Sub Basin, Andhra Pradesh (India)

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Abstract- Pedogeochemical sampling over an area of 45 Sq.Km was initially taken up in the Chitrial outlier, which is actually detached from the main Srisailam sub basin as a result of topographic low formed through weathering and erosional processes. Pedogeochemical sampling is carried out on a grid of 1Km x 1Km and various geochemically associated trace and ore elements viz., U,Th,V,Cr,Co,Ni,Cu,Pb,Zn and As are analyzed and studied for their dispersion patterns. The pedogeochemical dispersion pattern of trace elements studied in conjunction with geology and structure has yielded an area of 11 Sq.Km which is identified with specific trends (N-S and NNE-SSW), as a potential zone for uranium mineralization and is recommended for detailed and subsurface investigations.

Index Terms- Dispersion haloe, pedogeochemical, Srisailam sub basin, uranium.

I. Introduction

The mid-Proterozoic – Archean basement unconformity is proved all over the world as the most potential zone hosting some of the world's largest uranium deposits. The Srisailam sub basin is geologically mid to late Proterozoic in age and it is unconformably overlying the Archean granite basement. The sediments are essentially arenaceous and are represented by a basal pebbly quartzite, followed by a grey medium grained quartzite with grey to buff coloured shale as intercalations. The basement is represented by a coarse to medium grained grey fractured granite. Srisailam sub basin and cuddapah basin geology with known uranium mineralization.

Unconformity-related Uranium mineralization

With the discoveries of high grade mineralisation (~ 0.5% U3O8) of the unconformity-type in the Athabasca basin of Canada and the Pine creek geosynclines of Australia, (Hoeve , J. et al., 1980) emphasis on exploration was shifted in early 1990's to locate fracture controlled unconformity related uranium mineralisation in Cuddapah basin. Workable deposits of unconformity-related type have been established at Lambapur-Peddagattu, Nalgonda district and Koppunuru, Guntur district, Andhra Pradesh, along NW margin of the Cuddapah basin.

Fracture/Shear controlled uranium mineralisation

Fracture controlled uranium mineralisation is both basement granite hosted as well as sediment hosted (Gulcheru Formation, the oldest member of the Cuddapah Super Group) and occurs along the southern margin of the Cuddapah basin.

Strata bound Uranium mineralisation

The strata bound uranium-mineralisation in southwestern part of the Cuddapah basin is unique in the sense that no such strata bound uranium deposit hosted by carbonate rocks is reported in the world. Uranium mineralisation is hosted by impure phosphatic dolostone of the Vempalle Formation of the Papaghni Group. It extends from Chelumpalli in the northwest to Maddimadugu in the southeast over a belt of 160 km with promising mineralisation at Tummalapalle, Rachak-untapalli and Gadankipalli in the central part.

Significance of unconformity uranium deposits

An unconformity is a buried erosion surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous. In general, the older layer was exposed to erosion for an interval of time before deposition of the younger, but the term is used to describe any break in the sedimentary geologic record.

Unconformity-type uranium (Jefferson.C., et al., 2005) deposits host high grades relative to other uranium deposits and include some of the largest and richest deposits known. They occur in close proximity to major unconformities between relatively quartz-rich sandstones comprising the basal portion of relatively undeformed sedimentary basins and deformed metamorphic basement rocks. These sedimentary basins are typically of Proterozoic age, however some Phanerozoic examples exist. The most significant areas for this style of deposit are currently the Athabasca Basin in Saskatchewan, Canada, and the McArthur Basin in the Northern Territory, Australia.

The Proterozoic basins all over the world have gained importance in the light of high-grade unconformity related uranium deposits associated with them. The depositional conditions for that geologic time favored the chemical mobility of the uranium from their primary source to the sediments/host rocks and got deposited as different type of uranium deposits specific to their type and nature. In particular, the unconformity surface between the Proterozoic sediments and the Archean basement crystalline acted as the most favourable geochemical front/ surface with host of other favourable criteria like basement faults and folds, along with the clay horizons, reductants and alteration zones associated with the rocks proximal to the unconformity surface. The hydrothermal solution activity along with structural disturbances over the geologic times would have reactivated, remobilized and concentrated uranium along these surfaces.

Proterozoic unconformity and their environs are established potential target areas of medium to high grade, large tonnage, low cost uranium deposits in parts of Canada (Cigar lake) and Australia (Athabasca basin) and more than 50% of present day world production is recovered from such geological settings.

The classical geological setting of unconformity type uranium deposits is "the contact between Meso to Neo-Proterozoic sediments and Palaeo-Proterozoic metasediments". Such deposits are mainly located at or near the unconformity surface, (Senthil kumar, P., et al 2002) as it provides an effective plumbing system for circulation of hydrothermal solutions. Precipitation due to intermixing of highly charged metal rich oxidizing solutions from above and reducing solutions from below the unconformity and repeated recycling/ remobilization are the conspicuous features of such deposits imparting them unusually high grade.

Indian Scenario of Unconformity related uranium deposits: In India, first unconformity deposit was established in the intra-cratonic Proterozoic Cuddapah basin at Lambapur- Peddagattu, Nalgonda district (Sinha, 1995), and later at Koppunuru, Guntur district (Jeyagopal, 1996) at the proximity of unconformity contact of Meso-Proterozoic Srisailam quartzite/ Neo-Proterozoic Banganapalle quartzite and the basement granite respectively.

II. Geology and Structure

The Srisailam sub basin is located in the north eastern part of the Cuddapah basin. The Chitrial, area is located in the north eastern fringes of Srisailam sub basin (fig no.1). Chitrial outlier is horseshoe shaped and is located to the north of Dindi River which is flowing from northwest to southeast along lineament and merges with Nagarjunasagar reservoir.

The study area (45 Sq.km) falls around the known / established uranium mineralization at Chitrial. The area is located in the northern periphery of the Srisailam sub-basin. The area represents small Outlier of Quartzite (Srisailam formation). The area covers both the quartzite outliers and the basement granite, dolerite dykes, shale, clays are presented along the unconformity of the Chitrial outlier (fig no. 2), considering the importance of both the source and host for uranium mineralization. The fertile nature of the granite basement is a pre-requisite for unconformity type of uranium mineralization in Proterozoic basins.

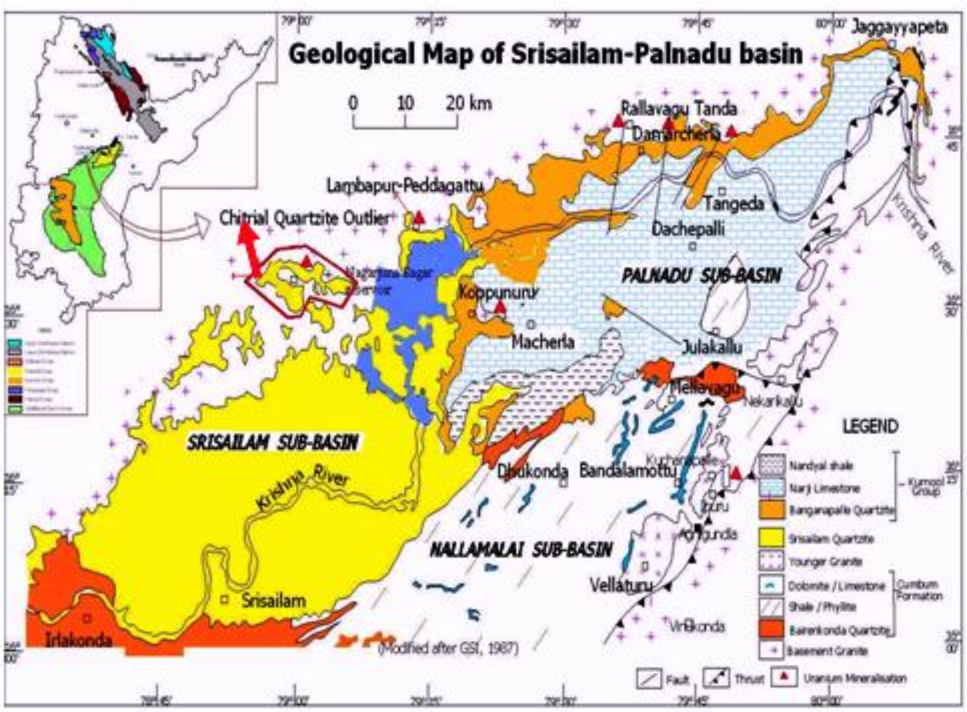

Figure 1. Location map of Chitrial outlier in Srisailam Sub basin (AMD)

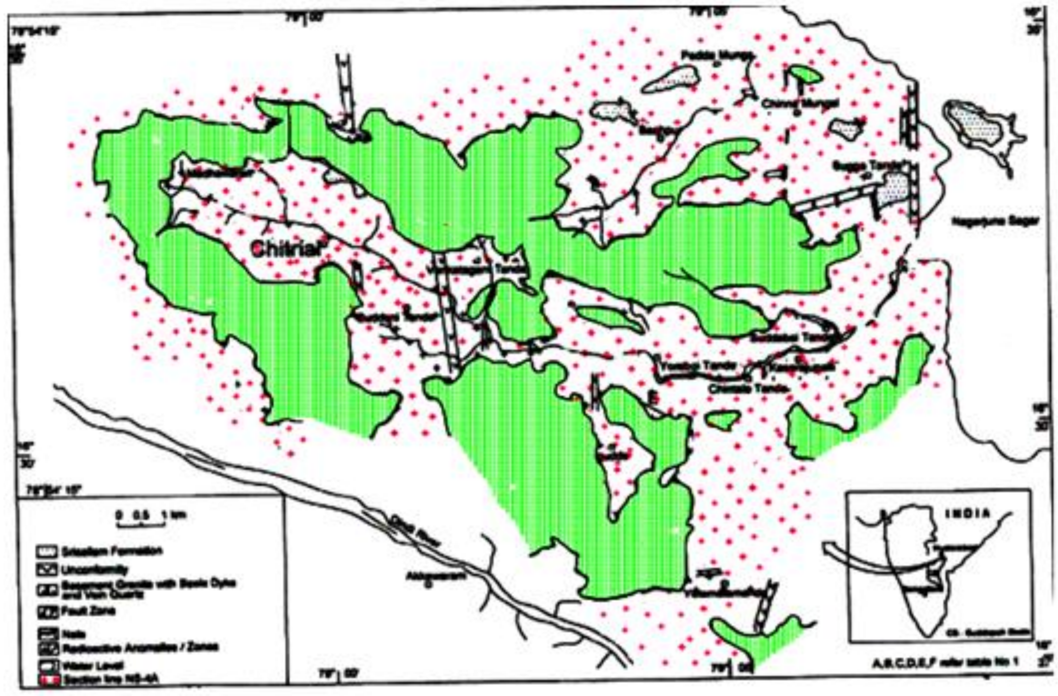

Figure 2. Geological map of Chitrial outlier (AMD, 2009)

Structure: A number of basement-dykes (dolerites) trending N-S and NNW-SSE and a minor trend represented by E -W are observed. The mineralization trend as established in the Chitrial area is also more or less in the N-S and NNW-SSE direction (fig 2). The Chitrial area has been dissected by NW-SE; NE-SW; and NS lineaments. The main drainage in the area Viz. Dindi and Krishna Rivers flow along WNW-ESE and N-S lineaments respectively. The joints in the basement show two distinct directions along NW-SE and NE-SW, with less developed directions of N-S and E-W.

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Table-1 - Geological succession in the Cuddapah Basin, after King {1872}

	Kundair Group
	Paniam Group
KURNOOL SYSTEM	**Jamalamadugu Group**
	Banganapalli Group
	---------------------*Unconformity*------------------
Kistna Group	**Srisailam Quartzite**
	Kolamnala Slate
	Iriakonda Quartzite
	--------------------- *Unconformity*------------------------
Nallamalai Group	**Cumbum Slate**
	Bairenkonda Quartzite
CUDDAPAH SYSTEM	---------------------*Unconformity*---------------------------
Cheyair Group	**Tadpatri Shale**
	Pulivendla Quartzite
	Nagari Quartzite
Papaghni Group	**Vempalle Slate**
	Gulcheru Quartzite
	-------------------- *Unconformity*--------------------------

Older Precambrian

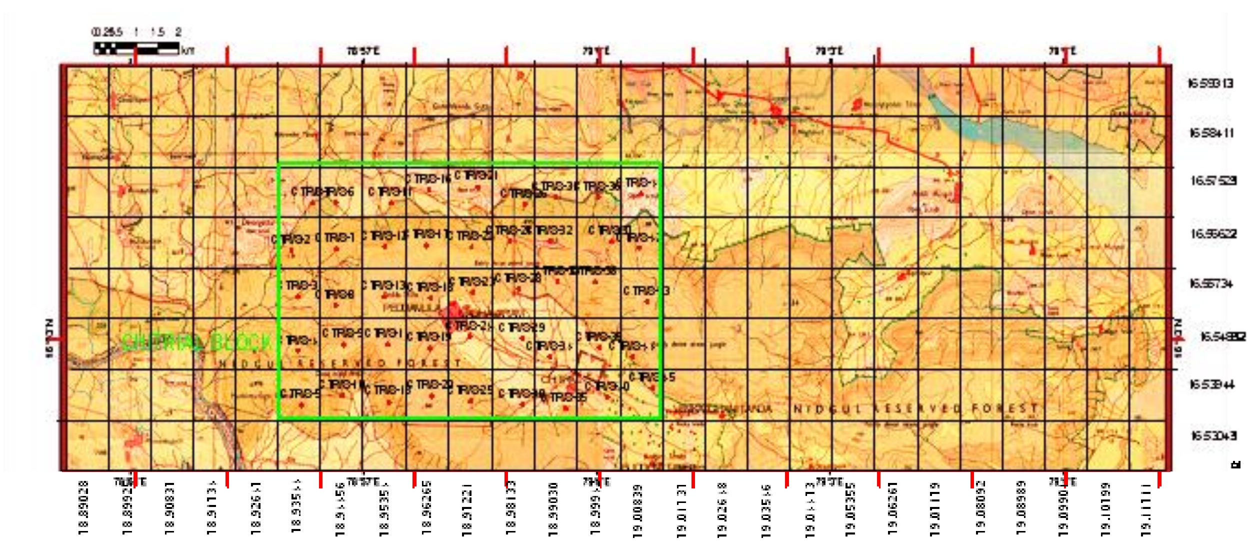

Figure3. Pedogeochemical sampling grid in Chitrial

III. Pedogeochemical Sampling

Pedogeochemical sampling is carried out on a grid of 1Km x 1Km (fig no.3) and various geochemically associated trace and ore elements viz., U,Th,V,Cr,Co,Ni,Cu,Pb,Zn and As are analyzed and studied for their dispersion patterns (Chaudary M.A. et al., 2002). The samples were sun dried and sieved to -80 mesh size for the chemical analysis in the field itself to save the time and transport cost. Before the analysis the samples were homogenized with quartering & conning, then take one gram of each of the soil samples were subjected to the cold acid partial digestion technique with 1:1 HCl to know the concentration of the transported mobile trace elements which help in knowing the adsorbed material around the soil particles into soil solution for analysis. The dispersion pattern of the trace elements w.r.t uranium mineralization. The solutions thus obtained were subjected to analysis on ICPMS at NGRI. (Balaram, V. et al., 2003).

Table no.2 Pedogeochemical Analysis results of Chitrial

longitude	latitude	sample no	V	Cr	Co	Ni	Cu	Zn	As	Pb	Th	U
78.93365	16.57418	CTR/S-1	92.15	24.88	22.02	23.48	20.51	57.29	0.00	667.43	0.00	18.84
78.935056	16.56575	CTR/S-2	118.07	24.88	33.64	21.70	21.14	51.69	0.00	35.22	6.96	22.85
78.934940	16.557656	CTR/S-3	51.78	17.55	16.00	14.72	10.20	27.34	0.00	15.22	4.68	11.85
78.935848	16.548076	CTR/S-4	107.85	31.79	27.67	37.27	21.41	84.28	0.00	40.61	54.50	25.97
78.943162	16.538358	CTR/S-5	140.93	43.02	23.42	26.18	25.67	51.15	0.00	31.80	10.31	5.92
78.943302	16.574324	CTR/S-6	54.70	19.90	18.59	17.82	11.77	60.75	0.00	30.33	4.18	3.79
78.943162	16.566116	CTR/S-7	95.45	29.57	23.66	25.21	20.01	77.06	0.00	631.42	12.38	10.67
78.944956	16.556147	CTR/S-8	41.51	11.98	16.47	10.63	7.64	28.30	0.00	21.86	7.46	13.56
78.944583	16.549082	CTR/S-9	85.08	30.62	25.67	20.09	61.73	94.36	0.00	569.11	11.76	4.43
78.955112	16.540142	CTR/S-10	77.88	20.08	28.32	27.83	18.06	65.62	0.00	33.94	5.41	14.32
78.953691	16.574187	CTR/S-11	523.98	33.89	69.61	48.88	111.25	31.03	0.00	3.67	1.19	1.41
78.953574	16.566505	CTR/S-12	84.07	29.25	26.06	35.00	13.36	41.59	0.00	15.78	1.62	5.34
78.954343	16.557656	CTR/S-13	108.41	30.60	30.88	20.46	15.65	9.06	0.00	16.64	3.93	1.43
78.954599	16.549219	CTR/S-14	60.20	22.59	13.73	16.93	7.00	9.08	0.00	14.17	0.71	0.72
78.963218	16.538999	CTR/S-15	121.96	31.07	31.82	29.41	23.72	114.99	0.00	40.22	26.63	8.05
78.962705	16.576474	CTR/S-16	65.06	21.19	6.77	12.68	9.22	16.32	0.00	8.25	0.83	0.08
78.963590	16.566619	CTR/S-17	59.63	15.56	20.97	23.02	12.30	28.89	0.00	14.41	3.54	1.14
78.963474	16.557405	CTR/S-18	71.60	20.12	17.73	26.45	12.55	27.70	0.00	12.48	2.93	0.90
78.963730	16.548465	CTR/S-19	70.99	28.12	16.04	21.00	8.69	16.14	0.00	13.00	0.89	1.13
78.973746	16.540005	CTR/S-20	72.90	29.03	26.49	24.55	10.98	64.85	0.00	671.77	14.48	9.37
78.972325	16.576977	CTR/S-21	65.73	22.67	20.69	20.47	13.18	27.78	0.00	32.25	0.96	0.84
78.972605	16.566368	CTR/S-22	135.83	37.66	32.93	52.62	25.11	21.05	0.00	16.63	1.55	0.56
78.971952	16.558296	CTR/S-23	95.05	21.31	28.05	35.66	24.66	42.58	0.00	31.79	3.34	6.73
78.972209	16.550591	CTR/S-24	118.52	25.43	35.56	34.41	26.82	143.31	0.00	705.51	39.04	3.75
78.983785	16.539113	CTR/S-25	46.70	17.49	21.51	16.47	13.37	22.68	0.00	10.55	2.02	0.15
78.980571	16.573936	CTR/S-26	112.31	30.11	41.46	24.42	22.31	21.21	0.00	18.07	3.10	0.20
78.982481	16.567374	CTR/S-27	86.93	20.93	29.92	26.83	12.29	46.65	0.00	34.88	18.07	3.08
78.983250	16.558937	CTR/S-28	46.63	13.50	19.07	32.56	7.00	37.20	0.00	18.37	3.73	2.04
78.983250	16.550339	CTR/S-29	51.19	18.25	27.47	17.66	12.39	28.30	1.98	12.64	0.79	0.88
78.990447	16.538495	CTR/S-30	77.78	24.78	37.94	31.66	15.75	25.21	2.26	18.38	1.26	3.69
78.989166	16.575193	CTR/S-31	67.44	15.21	18.75	184.27	12.74	72.17	2.10	42.95	10.36	29.85
78.990843	16.567511	CTR/S-32	97.54	35.80	16.89	21.75	15.18	15.12	2.16	13.02	0.41	1.49
78.989166	16.560194	CTR/S-33	78.43	23.23	30.75	32.80	18.85	16.41	2.23	12.93	1.35	1.55
78.992520	16.546933	CTR/S-34	75.10	20.48	23.57	33.26	19.84	31.16	2.03	18.83	0.77	3.47
78.999578	16.537855	CTR/S-35	50.11	18.61	21.27	11.77	9.72	8.11	1.51	8.95	0.88	0.88
79.002420	16.575193	CTR/S-36	132.86	48.67	52.62	41.23	30.82	65.27	1.89	43.89	11.43	8.05
78.998809	16.567374	CTR/S-37	54.96	19.47	28.31	18.61	15.70	43.60	1.45	68.00	25.71	19.46
78.999834	16.560194	CTR/S-38	65.96	36.14	20.50	39.58	15.67	23.14	1.15	17.64	3.31	2.17
79.001628	16.548579	CTR/S-39	99.34	39.97	32.30	32.02	26.39	15.65	1.24	24.06	5.91	3.16
79.008709	16.539890	CTR/S-40	35.03	17.53	25.88	39.06	14.35	28.53	1.40	19.64	3.13	18.19
79.008453	16.575834	CTR/S-41	52.69	22.80	26.38	18.86	18.81	49.84	0.99	45.41	12.04	7.70
79.010130	16.566253	CTR/S-42	64.74	26.77	35.23	29.73	26.64	92.79	1.13	61.04	9.22	36.70
79.006915	16.556787	CTR/S-43	99.27	40.14	24.22	22.94	18.26	12.26	1.06	26.26	7.08	3.58
79.011271	16.546933	CTR/S-44	113.25	36.62	60.29	50.08	36.07	30.08	0.95	34.57	5.75	2.73
79.011271	16.541514	CTR/S-45	93.81	36.95	37.46	50.58	29.84	80.23	1.09	49.00	7.77	8.11
		Avg	91.59	26.36	27.66	31.17	20.55	43.51	0.59	94.95	7.85	7.35
		St.D	0.98	0.67	0.59	0.46	0.69	0.71	0.00	13.62	0.00	2.32
		Threshold	93.55	27.71	28.83	127.17	116.55	44.93	0.59	122.19	7.85	12.00

IV. Correlation of Pedogeochemical Parameters

Correlation coefficient is commonly used measure to establish the relation between independent and dependent variable. The correlation matrix for 10 elements for Chitrial area in Srisailam sub basin.

Table no .3. Correlation matrix of 10 elements of study area.

	V	**Cr**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Pb**	**U**	**Th**
V	1.000									
Cr	0.434	1.000								
Co	**0.769**	0.477	1.000							
Ni	0.134	-0.010	0.116	1.000						
Cu	**0.895**	0.409	**0.739**	0.107	1.000					
Zn	0.085	0.129	0.192	0.214	0.212	1.000				
As	-0.146	0.042	0.103	0.321	-0.097	-0.224	1.000			
Pb	-0.004	0.105	0.018	0.055	0.150	**0.611**	-0.234	1.000		
U	-0.094	-0.151	-0.022	0.451	-0.068	0.413	0.067	0.168	1.000	
Th	0.035	0.150	0.154	0.090	0.061	**0.728**	-0.158	0.312	0.453	1.000

According to Karl Pearson from above table explained the Co &V, Cu & V, Cu & Co, Th & Zn shows best correlation between them. Pb & Zn shows good correlation. The remaining elements shows positive and some are related to negative correlationship.

V. Results and Discussions

The secondary dispersion of geochemically associated elements are i.e. U, Th, V, Cr and Ni shows NE – SW trend, which is also reflected extent in the secondary environment. The secondary dispersion haloe, these elements are Cu, Pb, Co, Zn and As which are can be related to the possible hydrothermal sulphide mineralization is observed in primary environment and more dispersed with a distinct of trend to NNE – SSW in secondary environment. The mineralization trends are explained with concentration maps below. Elements like U, Th, V, Cr, Co, Ni, Cu, Pb, Zn, & As, are expressed in ppm levels. The main theme of this study area to find out the mineralization in the unconformity related uranium deposits. The maximum range of uranium is 1 ppm in soils, the study area consisting of U concentration (fig 4) is maximum 29.85 ppm and minimum is 0.081 ppm. The average value of all samples 7.18 ppm; the threshold value is 12 ppm. Thorium concentration (fig 5) containing the highest value is 54.50 and lowest value is 0 ppm average value is 8.71 ppm, the threshold value is 7.85 ppm, naturally the average abundance of thorium is 13 ppm in soils, and some samples have high values compare with desirable limit. Pb concentration (fig 11) consisting of maximum value is 705.51 ppm, minimum value is 3.6 ppm the average value is 113.46 ppm, the threshold value is 122.19, the common abundance value is 2-200 ppm in soils, 60% of soil samples showing above permissible limit. Arsenic concentration (fig 13) containing maximum value is 2.26 ppm, minimum value is nil, the average value is 0.59 ppm, the threshold value is 0.59 ppm, the permissible limit is 1-50 ppm in soils, no sample exceeds the limit. Zn concentration (fig 12) consisting of 143.30 ppm at maximum, 8.10 ppm is minimum and the average is 43.90 ppm, the threshold value is 44.93 ppm, natural abundance of Zn is present in 10-300 ppm in soils. Cu concentration (fig 10) having highest value is 111.24 ppm, the minimum value is 6.99 ppm and the average is 21.74 ppm, the threshold value is 116.55 ppm, the permissible limit is 2-100 ppm in soils, one sample is exceeds the limit. Ni concentration (fig 9) maximum value is 184.26 ppm, minimum is 10.62 ppm the average value is 33.93, the threshold value is 127.17 ppm, Co concentration (fig 8) maximum value is 69.60 ppm, the minimum value is 6.77 ppm, the average value is 27.08, the threshold is 28.83 ppm, the natural abundance of Co is 1-40 ppm in soils, and some samples exceed the permissible limits. Vanadium concentration (fig no. 6) maximum value is 523.97 ppm, minimum is 35.02 ppm, the threshold is 93.55 ppm, the permissible limit is 20-500 ppm in soils, and some samples exceed the limit. Cr concentration (fig 7) maximum value is 48.66 ppm; minimum value is 11.98 ppm the average value is 28.79 ppm, the threshold value is 27.71 ppm, the permissible limit is 5-1000 ppm in soils, no one sample exceed the permissible limit.

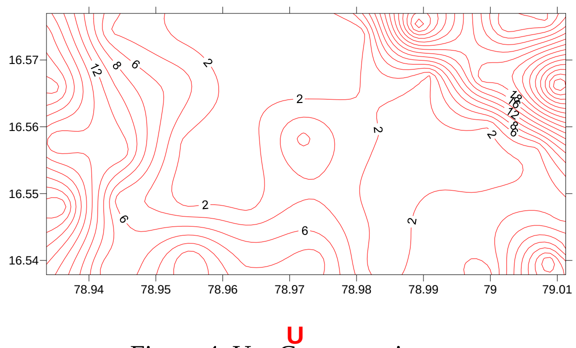

Fig no 4. U – Concentration

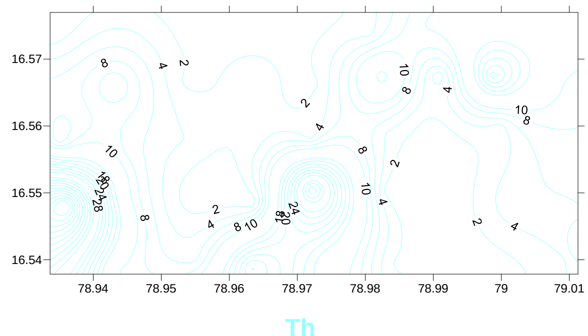

Fig no 5. Th – Concentration

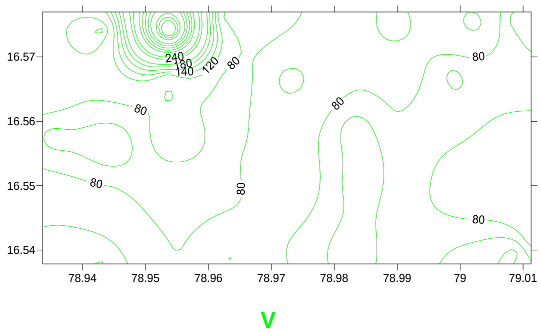

Fig no 6. V – Concentration

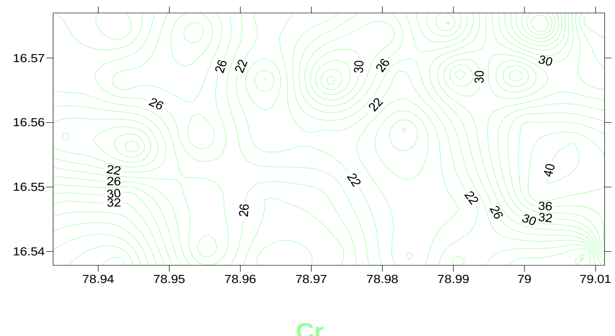

Fig no 7. Cr – Concentration

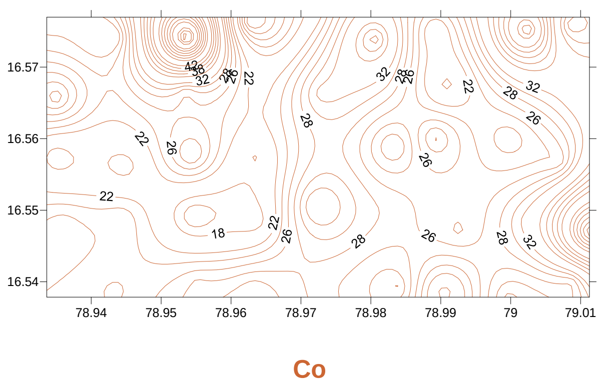

Fig no 8. Co – Concentration

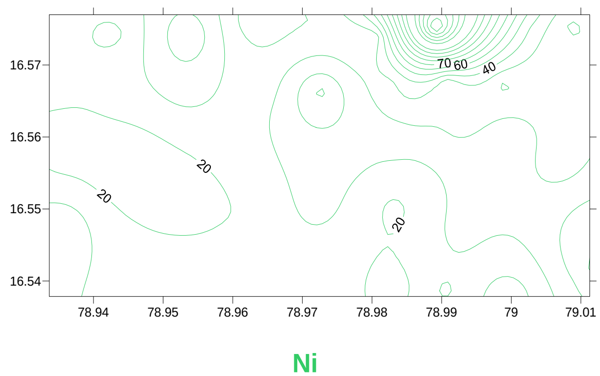

Fig no 9. Ni– Concentration

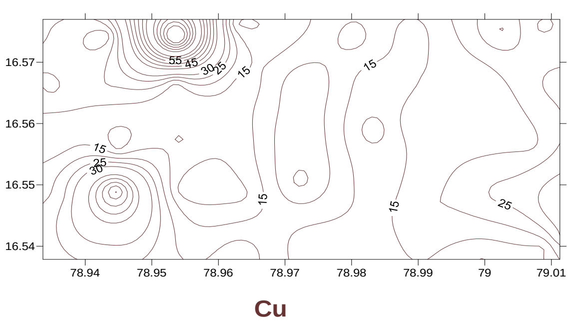

Fig no 10. Cu – Concentration

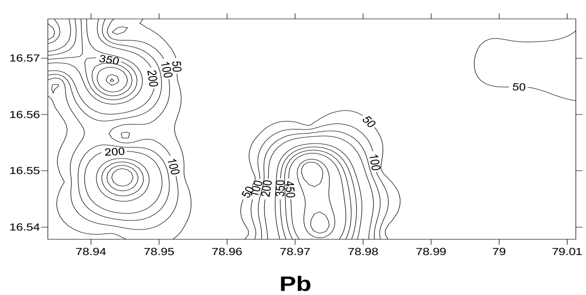

Fig no 11.Pb – Concentration

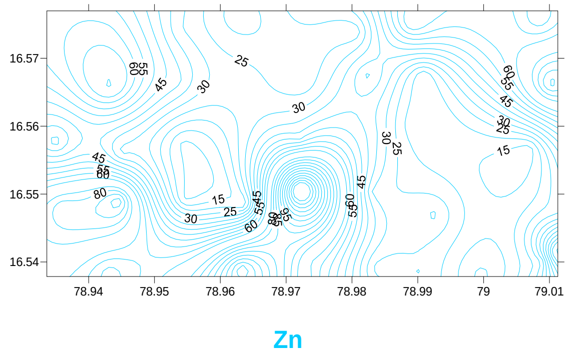

Fig no 12. Zn – Concentration

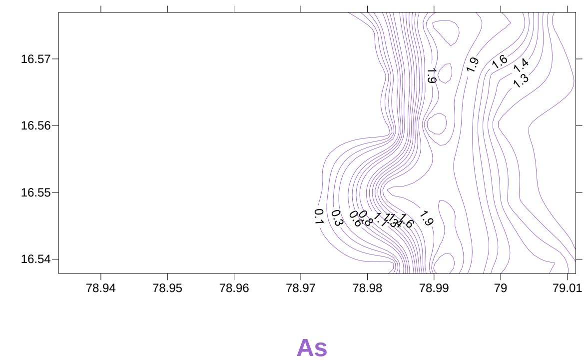

Fig no 13. As – Concentration

VI. Conclusion

Significance of sub surface mineralization located at the unconformity contact of basement granitiod with Srisailam sub basin, around the Chitrial, Nalgonda District, and Andhra Pradesh led to establishment of sizeable uranium mineralization. Thus intensive sub surface investigation resulted in delineating the persistency of mineralization over the 11 Km. An attempt has been made to synthesize the exploratory history commencing from locating uranium occurrences up to developing them into workable economic deposit in Chitrial. Based on the geology, structure and pedogeochemical (secondary dispersion haloes) results, the Chitrial area has been recommended for detailed and subsurface investigations and delineate of target zone for Uranium mineralization (11 Sq.Km) which is identified with specific trends (N-S and NNE-SSW), as a potential zone.

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