Mineral Explorations of Cu-Pb-Zn deposits of Sikar District, Rajasthan, India

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Abstract: ***The Geophysical methods are one of the indirect techniques to understand the subsurface geology and its associated features. In geophysical exploration, measurements will be taken on the earth's surface/ boreholes to determine distributions of physical properties at depths that reflect subsurface geology. Magnesium-bearing calcretes of soft-gritty and hard pan varieties containing uranium concentrations from 16 to 74 ppm with <10 ppm of thorium are located along the palaeochannel at Narsingpuri to Gumansingke Dani village, Sikar district, Rajasthan. The uranium- bearing calcretes are exposed over an area extent of 300m and 200 m with thickness of up to 2 m in an inter- dunal depression. The silty sand layer occurring below the calcrete horizon suggests that it is a valley-fill cal- Crete, deposited along a palaeochannel. This occur- rence of uraniferous Mg-calcrete in the Palaeochannel opens up a large area for ura- nium exploration in the calcrete environment of Thar Desert. These calcretes are composed of 15.94% to 25.39% CaO, 7.15% to 22.39% MgO and Sr/Ba ratio up to 66.98. There is a positive correlation of U with Sr/Ba and MgO. The high Sr/Ba ratio and MgO indi- cate water of saline nature and high rate of evapora- tion. Ephemeral centripetal drainage mixing with the dissected palaeochannel waters and groundwater's, under arid climatic conditions might have resulted in the formation of this kind of uranium-bearing calcrete in fluvio-lacustrine environment.***

Keywords: Fluvio-lacustrine environment, Sikar, magnesium calcrete, surgical type uranium

1. Introduction

The science of geophysics applies the principles of physics to the study of the Earth. Geophysical investigations of the interior of the Earth involve taking measurements at or near the Earth's surface that are influenced by the internal distribution of physical properties. Analysis of these measurements can reveal how the physical properties of the earth's interior vary vertically and laterally.

An alternative method of investigating subsurface geology is by drilling boreholes, but these are expensive and provide information only at discrete locations. Geophysical surveying, provides a relatively rapid and cost effective means of inferring subsurface geology. In the exploration for subsurface resources these methods are capable of detecting and delineating features of potential interest.

A detailed Geophysical Survey was carried out in the area in between **Gumansingdhani & Narsingpuri villages, Sikar** D**istrict of Rajasthan** for identifying favorable subsurface targets that hold Uranium mineralization.

2. Objectives

- To get acquainted with practical knowledge of data collection, processing and interpretation of ground geophysical methods like Resistivity/Induced Polarization, Gravity and Magnetic methods.
- To delineate favorable geological structures controlling uranium mineralization which is reported to occur within the unconformity contact of sediments and basement of Khetri sub-basin, Gumansing dhani village.

3. Review of Literature

Ballhaus, C., Ryan, C.G., 1995. Platinum-group elements in the Merensky reef. I. PGE in solid solution in base metals sulfides and the down-temperature equilibration history of Merensky ores. Contrib. Mineral. Petrol.

Ballhaus, C., Sylvester, P., 2000. PGE enrichment processes in the Merensky reef. J. Petrol.

4. Methodology

- Base line is chosen along North East-South West direction which is parallel to the general strike of the geological formations.
- The profile lines were chosen along North West – South East direction at every 100m interval as the strike was along North East –South West direction.
- Along the profile the station interval is 25m.
- The length of the profile line is 1 km in South East side and 1.6 km in North West side.
- The target area is 6 sq.km
- Resistivity survey was conducted using Dipole-Dipole array configuration along the profiles
- Suitable base station was selected for magnetic survey which is at the camp office located at Bhairu Ghats, Udaypurwati, JhunJunu dist, Rajasthan.
- Gravity survey base station is established at P-13(origin point) near Gumansing dhani (village).
- Data processing work included corrections to the data, calculation of anomalies and data plotting to generate profiles and contour maps.
- Integrating all the available geophysical, geological information for interpretation of the subsurface anomaly features for targeting the conductive zone and delineation of geological structure in the study area.

Geology:
The Proterozoic basin (Aravalli-Dehli) of the northwestern India is one of the prime targets for uranium exploration. Exploration over decades in this basin has established fracture controlled type and albitite type uranium

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mineralization mainly in Delhi Super group of rocks. Besides this a number of sulphide deposits like Khetri, Kho-Dariba, Bhagoni etc., also occur in the Delhi Fold Belt (North Delhi Fold Belt).

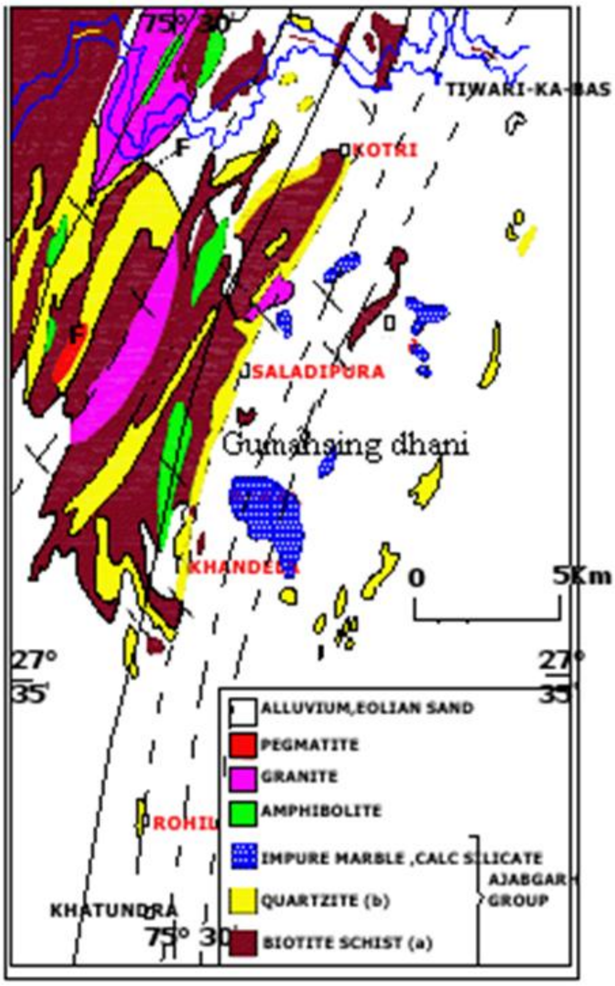
The Rohil-Ghateswar sector and Saladipura sectors of NDFB, the radioactive albitite outcrops measure 30-500m 5-30m. Exploration by AMD and GSI in early 70's has established fairly co relatable uranium mineralization associated with molybdenum at different subsurface levels in albitites. Uranium mineralization in this area closely follows the contact of quartzite's and quartz-biotitic schists (with or without graphite's and sulphides) of Ajabgarh Group of Delhi Super group. This sector is characterized by typical geophysical signatures of low magnetic, high chargeability and low resistivity zones indicating presence of sulphide mineralization (and its association with uranium mineralization) along weak structural planes. Presence of EM conductors (caused by massive sulphides and graphitic schists) are also geophysical guides of exploration in this area. Sizeable uranium deposit of low grade, low tonnage has already been established in Rohil- Ghateshwar sector.

Local Geology of Gumansingke-dhani area:

Gumansingke-dhani area is situated north east of Narsingpuri sector having sporadic surface manifestation of radioactivity, hosted by albitized quartz biotitic schist (QBS), and Pyroxenites. Few boreholes drilled in the area have indicated persistency of uranium mineralization at depths. Geophysical surveys during earlier field seasons in the area have indicated zones of high chargeability, low resistivity. These zones are mostly soil covered. During the current Field season, detailed geophysical surveys are carried out in Gumansingke-dhani sector to trace the zones of high chargeability, magnetic lows and low resistivity for delineation of sulphide mineralization and associated uranium mineralization

Geophysical surveys comprising of Induced polarization (Time domain) and magnetic methods covering an area of 2 sq km, and electromagnetic methods along selected profiles are carried out in the area. Few geological traverses in the area indicate pervasive albitisation of the rock types such as QBS, pyroxinites garnetiferous biotite schist and calcsilicates. These albitites are traversed by quartz veins and calcite veins. All the formations have a general trend of NE-SW of the area, although variations in the trend have been also observed in the area. Fluorite mineralization is also observed in the area along with the quartz veins.

Geological Map showing location of Gumansing Dhani to Narsingh Puri, Sikar (Dist.), Rajasthan



Geochemical Data Analysis

There are two types of calcretes: one is pale white, soft and friable, nodular to columnar 'gritty' type. The other variety is a white, hard and compact 'hardpan' type. Both these varieties contain uranium concentration and the soft variety holds higher concentration than hardpan. Thickness of calcrete horizon varies from 0.50 to 2.50 m with an average of 2 m and the contact between calcrete and the underlying khaki-green silty-sand unit is sharp. It is suggested that the green sand below the calcrete in the interlunar areas represents vestiges of an earlier disorganized drainage system1.

Three cross-sectional profiles were selected within the quarry and systematic grab samples (n = 18) were collected from both these calcrete and silty-sand horizons. Uranium was estimated through standard flourimetry13, and thorium, strontium, barium, calcium and magnesium were estimated though ICP-AES and potassium by flame photometry. These analytical results are provided.

The analysis of data reveals that uranium values in calcretes vary from 16 to 74 ppm and in silty-sand horizon it is <5 ppm. Thorium concentration in both these units is <10 ppm. The CaO ranges from 15.94% to 25.39% and MgO from 7.15% to 22.39%. Literature survey shows that the world average of CaO content in calcretes varies from 39.5% to 44.5% and MgO does not exceed 3% and average Indian

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calcretes are less calcareous as compared to global average. Mg-rich calcretes have been reported from Australia, South Africa and Namibia

The analysis of data indicates that strontium content varies from 1649 to 6229 ppm, barium ranges between 83 and 176 ppm. Sr/Ba ratio varies from 13.06 to 66.98. Strontium is generally associated with calcium-bearing evaporate sediments, whereas barium is associated with clastic sand; the higher Sr/Ba ratio indicates the nonclastic nature of sediments. Accordingly, analysis of the silty-sand (clasticsediment) horizon at the base of calcrete showed low MgO up to 1.56% and accordingly uranium <5 ppm and Sr/Ba ratio up to 0.96. There is a distinct chemical variation, especially in Sr/Ba ratio between clastic and non-clastic (evaporate) sediments. Silty-sand horizon contains high potassium concentration up to 1.24% and accordingly there are moderate levels of barium concentration up to 300 ppm. This may occur due to presence of clay minerals within the silty-sand horizon. The linear association relationship of U with Sr/Ba and MgO using co-efficient of correlation analysis there is a moderate positive correlation between U and MgO and Sr/Ba with the co-efficient of correlation (*r*2) values of 0.525 and 0.728 respectively. Studies carried out on sub-surface playa sediment-calcrete from different playas in western Rajasthan; suggest that the prevalence of higher evaporation and salinity conditions favours high Sr/Ba ratio and strontium is associated with carbonate and sulphate bearing minerals and these are genetically contain evaporates, whereas barium is derived from clastic sediments15. Similar studies on calcrete from Kalahari Desert area attributed high magnesium concentration in calcretes to high rate of evaporation16. The high Sr/Ba ratio and MgO contents indicate the high rate of evaporation which favours the dissociation of urinal carbonate complex in the waters forming uranyl ions in solutions.

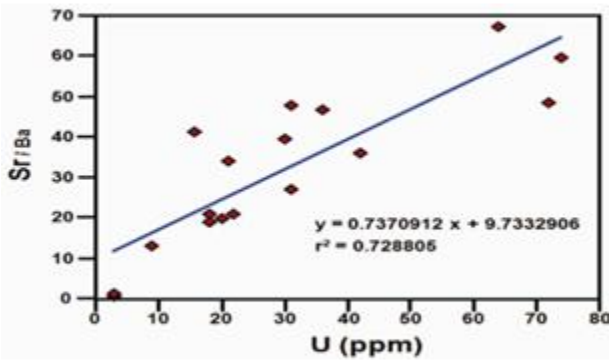

Figure 2: U (ppm) versus Sr/Ba

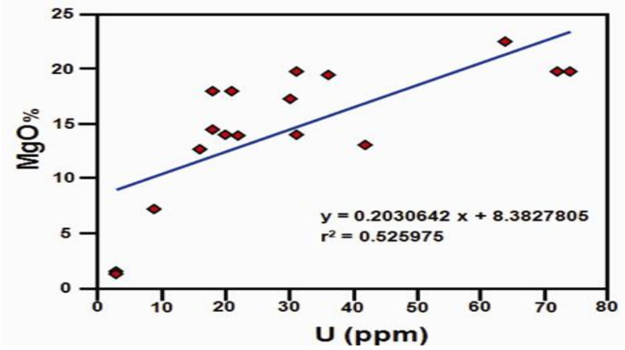

Figure 3: U (ppm) versus MgO (%)

5. Results and Discussions

It is established that hydro geochemical surveys play a major role in exploration for uranium-bearing calcretes. For this purpose, eight water samples were collected from different open wells, hand pumps and tube wells along the palaeo-channels. The general water table depth varies between 15 and 25 m. Samples were collected in dupli-cate in 250 ml prewashed polythene bottles. The waters were filtered through 0.45 micron filter paper and one set of samples was acidified to pH 2 using 10% nitric acid, to prevent flocculation and fungus formation, thus arresting the adsorption of uranium. This facilitated the reliability and precision of uranium values. The acidified samples were used for estimation of uranium through laser flourimetry The other set of non-acidified samples were used for estimation of major cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) and major anions (HCO^{-}, Cl^{2-}, SO) using standard proce dures[19]. The results indicate that Ca^{++} ranges from 145 to 212 ppm, Mg^{++} ranges from 15 to 102 ppm, Na^{+} ranges from 45 to 212 ppm, K^{+} ranges from 3 to 12 ppm, HCO^{-} ranges from 257 to 565 ppm, Cl^{-} ranges from 250 to 1415 ppm, $SO^{- -}$ ranges from 123 to 248 ppm and V ranges from 16 to 55 ppb. During sample collection itself, the Eh and pH values were measured using ORP and pH meters respectively. The Eh values vary between +125 and +275 mV and pH values range between 7.5 and 8.

Table 1: Chemical analysis data of calcretes from Sikar district, Rajasthan

Sample no.	Rock type	U (ppm)	Th (ppm)	CaO (wt%)	MgO (wt%)	Sr (ppm)	Ba (ppm)	Sr/Ba	V (ppm)	K_2O (%)
SKR/150	Soft powdery calcrete	30	<10	20.50	17.32	3514	90	39.04	11	0.32
SKR/151	Hardpan calcrete	16	<10	16.76	12.66	3574	87	41.08	14	0.17
SKR/152	Silty-sand	<5	<10	2.20	1.32	238	247	0.96	36	1.24
SKR/153	Soft powdery calcrete	31	<10	21.80	13.93	3367	125	26.94	10	0.38
SKR/154	Hardpan calcrete	20	<10	24.09	14.04	1649	83	19.87	<10	0.29
SKR/155	Silty-sand	<5	<10	2.40	1.56	231	249	0.93	28	1.15
SKR/156	Soft powdery calcrete	31	<10	16.37	19.64	5608	118	47.53	20	0.23
SKR/157	Hardpan calcrete	16	<10	25.39	7.15	1946	149	13.06	13	0.51
SKR/158	Silty-sand	<5	<10	2.43	1.51	273	300	0.91	21	1.05
SKR/159		72	<10	19.78	19.72	5247	109	48.14	13	0.19

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SKR/160		74	<10	20.42	19.68	6013	101	59.53	12	0.16
SKR/161	Soft powdery calcrete	42	<10	23.39	13.06	4993	139	35.92	14	0.24
SKR/162		64	<10	16.37	22.39	6229	93	66.98	16	0.26
SKR/163		36	<10	19.18	19.49	5159	111	46.48	12	0.22
SKR/164		18	<10	23.63	14.41	2528	121	20.89	11	0.36
SKR/165	Hardpan calcrete	22	<10	21.44	13.81	2248	107	21.01	13	0.42
SKR/166		18	<10	15.94	18.00	2359	176	13.40	39	0.15
SKR/167		21	<10	17.73	17.89	4582	135	33.94	17	0.23

The data indicate that waters are oxidized, saline and alkaline. Uranium-bearing calcretes generally formed from mildy oxidizing, saline alkaline ground waters. In constricted drainages to semi-enclosed basins under variable evaporative conditions[20]. The present uranium- bearing calcretes were identified in the dry small playa along the channel with green silty sand at the base. This kind of semi-enclosed loci is of fluvio- lacustrine nature and formed by the dissection/ segmentation of palaeo channels and was admixed with fluctuating ground waters and centripetal ephemeral drainages draining through sand dunes, during seasonal rains. It is suggested that the green silty-sand in the inter- dunal areas represents vestiges of an earlier disorganized drainage system[12]. The high rate of evaporation under arid conditions resulted in an increase of total dissolved solids (TDS, 1225–3075 ppm) and waters gradually become brackish to saline. Accordingly, calcium and car- bonate ions were enriched and saturated within the waters.

6. Conclusion

One sample from Narsingh puri area indicates under saturation (39.91% SiO2), containing normative nepheline, leucite and diopside. In this sample, nepheline and leucite might have formed instead of albite and microcline due to the less silica availability. In general, CaO increases with decreasing Na2O content, suggesting that soda metasomatism was accompanied by carbonate precipitation. List the major, minor and CIPW normative minerals of albitite and associated rocks. Albitites are often associated with deep-seated fault systems and the sodium- rich solutions mobilized by metamorphic or anatectic process may be mixed with meteoric water or mantle-derived fluids. Many uranium deposits are known to occur in soda-rich rocks. The ‘uraniferous albitite zone’ defined here has geological and structural set-up akin to that of the albitite line1, and therefore assumes signi- ficance for U–REE and other kinds of polymetallic mineralization.

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