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Original Research Paper

Geochemical Exploration of Uranium Mineralization in Rock Formations from Central India: A Review on Earlier Reports

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ABSTRACT

A study of distribution of dissolved radon isotope Rn^{222} in borewell water revealed clusters of anomalies. Radioactive expressions in water are because of the high solubility of U, Ra and Rn in water, which facilitates to dissolve these from uranium mineralized rock. Geo-electrical and electromagnetic surveys conducted in different geological set up in Central India, brought out effectiveness of these methods in interpreting sub-surface locales of uranium mineralization that are associated with conducting minerals with sulphides, graphites/carbonaceous matter, alteration zones, structural features and shear zones, which have distinct electrical resistivity contrast with respect to the host rocks.

INTRODUCTION

Uranium is of immense importance for nuclear and power applications, and its demand is on a continuous increase with ever changing technologies and fast pace of development. It is commercially recovered from various rock types in the geological setup ranging from Precambrian crystallines and sediments/metasediments to Neogene sediments (calcrete deposits). As much as Central India (Maharashtra, Madhya Pradesh, Chhattisgarh and Orissa) is concerned, it has been hosted by a number of Proterozoic and Phanerozoic basins, which have exhibited conducive geological environments and the potential for these minerals. Different types of uranium mineralization viz., unconformity related, vein, sandstone, quartz-pebble conglomerate (QPC), iron oxide breccias (IOB) etc. RM & REE mineralization is associated with pegmatites and inland riverine placers.

Exploration activities for atomic minerals in Central India have altered considerably from the earlier approach of vein and sandstone type models, to recent unconformity related model based on the discovery of such high grade, large tonnage deposits elsewhere in the world as well as development in the exploration technology and advancement in understanding of uranium mineralization processes. Earlier radiometric surveys coupled with exploratory drilling and mining activities have established small tonnage, low grade vein type of uranium deposits associated with acid and basic volcanic, in cataclasite and granites. In addition, significant uranium mineralization associated with Gondwana sediments has been located in Polapathar Bhawra area, Betul district, Madhya Pradesh and eastern part of Tatapani-Ramkola basin, Surguja district, Chhattisgarh. Integrated evaluation of these areas using aerial survey and remote sensing (ASRS), geological, geochemical and geophysical surveys have brought into light several other uranium occurrences associated with basement complex, especially in Surguja crystallines, Kotri-Dongargarh belt, Nanded granitoids and infra-trappeans spread over in different parts of Chhattisgarh, Madhya Pradesh and Maharashtra.

A new model based approach involving multidisciplinary exploration techniques with bias on geophysical and geochemical methods has shown encouraging indication for unconformity related mineralization at Silekjhodi in Indravati basin, Sukma in Sukma basin, Chitakhol in Chhattisgarh basin and Baskati-Paniha-Khurmucha in Vindhyan Mahakoshal basin. Mineralization is proximally associated with unconformity between the Palaeoproterozoic basement rocks and the Meso to Neoproterozoic cover sediments. Similarly, exploration of Upper Gondwana sediments based on reducing model, where gas seeping from below through major fractures acts as reductant for fixation of uranium, has indicated sandstone type uranium mineralization at Thirpa-Kharatoriya area, Chhindwara district, Madhya Pradesh. Proterozoic basins of Central India have also shown potential for QPC and JOB type uranium mineralization at the base of the Bailadila Group in the environs of banded iron ore formations and along Kotri rift zone, respectively. The recent discovery of Gotulmura anomaly near Dalli Rajhara shows QPC setup while uranium-anomaly near Bhuski has JOB type signatures. In the present paper, an attempt has been made to discuss about the tools of geochemical exploration of uranium mineralization. A broad review is presented with the observations made in this direction, by various geoscientist and geological organizations.

Dissolved radon (^{222}Rn) in groundwater: Radon is an inert gas produced by the radioactive decay of the element radium in a long series of decay of uranium and thorium. Radon being gas has greater mobility than uranium and radium, which are fixed in the solid matter in rocks and soils. Radon has a tendency to migrate easily and deposit along fractures and openings in rocks. It also has the capability to accumulate in pore spaces between grains of soil. In uranium exploration, radon emanometry finds wide application to locate and trace extensions of radioactive anomalies, especially in the soil covered areas (Dyck 1980, Gingrich 1984).

Radon is a colourless, odourless, tasteless, radioactive, densest, noble gas, produced by radioactive decay of radium in long series of decay of uranium and thorium. It is sparingly soluble in water, but more soluble than lighter noble gases. It is appreciably more soluble in organic liquids (Kamlesh Kumar et al. 2010).

Radon is an alpha emitter and has several radioactive isotopes. Its most stable isotope, ^{222}Pn is a decay product of ^{238}U, and has a half life of 3.823 days. The ^{220}Rn isotope having a half life of 55.6 seconds is a natural decay product of the thorium (^{232}Th), and is commonly referred to as thoron. Similarly, ^{219}Rn is derived from the most stable isotope of actinium (^{227}Ac) named 'actinon' with a half-life of 3.96 seconds. Radon content in the open air ranges from 1 to 100 Bq/m^3, even less (0.1 Bq/m^3) above the ocean. High concentrations of radon have been found in some spring waters e.g. Akashiganga spring, Assam (Raju 1998). Being a noble gas, it usually migrates freely through faults and may accumulate in caves or water. Due to its very short half-life (3.823 days for ^{222}Rn), its concentration decreases rapidly when the distance from the source rock increases. Season and atmospheric conditions also affect radon concentration. Emanations of ^{222}Rn is expected to be more from the rock having more intrinsic uranium like granites, pegmatites and uranium mineralized rocks. When groundwater percolates through these uranium rich rocks, it is expected to contain more dissolved ^{222}Rn in groundwater. Radon can migrate to long distances from its source through several processes mainly by groundwater (Kamlesh Kumar et al. 2010).

Geological setup of the study area: The Mesoproterozoic Indravati Basin is located on the southern tip of Bastar craton (Naqvi & Rogers 1987), which is occupied by gneisses and granitoids of batholithic dimensions with meta-sediments and supracrustal rocks of Archaeoproterozoic age (Ramakrishnan 1990). The flat lying unmetamorphosed less disturbed arenite-shale-limestone package of cover sediments designated as Indravati Group are unconformably lying over highly disturbed, metamorphosed basement rocks (Dutt 1963). Basement rock of Indravati Basin is predominantly occupied by Darba granite and gneisses all around the basin, in general. Metabasalt and metasediments of Bengpal Group form the basement on the southern margin in addition to Darba Granite. Narrow granulite belt occurs below the sediments along the northern margin of the basin.

Radon concentration in groundwater: Indravati basin, having an area of 9000 km^2, exhibits several criteria favourable for unconformity-related uranium mineralization. A total of 137 groundwater samples were collected by Kamlesh Kumar and others for water radon measurement (Kamlesh Kumar et al. 2010). These borewells are located in three sectors of Indravati Basin. The radon counts (^{222}Rn) range from 46 to 47207 counts/50 sec with mean of 574 counts /50 sec, standard deviation of 444 counts/50 sec and threshold value of 1462 counts/50 sec (mean + 2 SD). The related data are presented in Table 1.

Geo-electrical surveys for uranium exploration: In uranium exploration, non-radiometric geophysical methods are generally used as an indirect tool to locate concealed deposits. Uranium mineralization is normally associated with sulphides, graphites/carbonaceous matter, alteration zones, structural features and shear zones, which have distinct electrical resistivity contrast with respect to host rocks (Kumar et al. 2007). Geo-electrical and electromagnetic techniques are generally carried out as a follow up to regional scale gravity and magnetic surveys for locating these features. Following are some case studies, wherein these surveys were involved, resulting into a positive indication of uranium mineralization.

Very low frequency-elecrtomagnetic (VLF-EM) surveys: The survey was carried out in Juba area, Raigad district, Chattisgarh by Kumar et al. (2007). The study area lies in the eastern margin of Singhora basin. The feldspathic arenite, polimictite conglomerate, shale and porcellanite rocks of Rehitikhol Formation of Singhora group of Chattisgarh Supergroup are disposed in the study area (Kumar et al. 2007). Radioactivity occurs in the pyritiferous feldspathic arenite and is structurally controlled by fault/fractures within the basement. Uranium minerals like Uraninite, Pitchblend and Coffinite occur in close association with sulphides (Tiwary 1997). The VLF-EM survey was tuned to the transmitting frequency of 22.2 KHz. The resistivity map thus generated, pointed out three prominent low resistivity zones.

Table 1: Sector-wise details of Radon (^{222}Rn) anomalies (after Kamlesh Kumar et al. 2007)

Sector	No. of Samples	Range Rn counts/50 sec.	Details of Radon Anomalies			
			Location	Longitude	Latitude	Rn counts / 50 second
Thumpani	34	197 – 33717	Thumpani	81.8053	19.0822	33717
Ransargipal			Barupatta	81.7664	19.0561	2580
			Barupatta Salepal	81.7794	19.0689	4280
			Dabriguda	81.7995	19.0564	2741
Kohkapal	73	46 – 7074	Dabriguda	81.9075	19.1064	3376
Karanji			Ransargipal	81.8575	19.0842	3682
			Kohkapal Karanji	81.8583	19.0858	2520
			Kohkapal Karanji			
Burgibhata	21	65 – 20394		81.9217	19.1147	3333
Koikamari			Burgibhata Munga	81.9175	19.1147	7074
			Koikamari	81.9194	19.1033	3554
			Kesharpal	81.9222	19.1070	2981
			Kesharpal			
Kesharpal	9	1332 - 47207	Kesharpal	81.8133	18.9425	3436
			Kesharpal	81.8240	18.9250	20394
			Kesharpal	81.7358	18.9528	2457
			Kesharpal	81.9006	19.3764	47207
			Kesharpal	81.9047	19.3775	3298
				81.8989	19.3747	4528
				81.9011	19.3781	11676
				81.9014	19.3769	3903
				81.9022	19.3800	8553
				81.9014	19.3800	2551

These zones correspond to the basement fault and corroborates well with the fault identified from the magnetic survey that was carried out earlier. The borehole drilled in one of the zones intercepted low-grade uranium mineralization in the sub-surface fault/fracture zone conforming structural control for the uranium mineralization (Kumar et al. 2007).

Horizontal loop electromagnetic (HLEM) survey: The survey was carried out in Damdam area of Raigad district, Chattisgarh by Kumar et al. (2007). The area falls in the southeastern margin of Chattisgarh basin. The area exposes basement granite, where uranium mineralization was identified in altered and fractured granites (Mukundhan & Srivastava 1999). The EM response was noted at shallow depth. Subsequent drilling of the fractured zones identified from HLEM surveys intercepted the altered braccia/fracture zone within the basement granite having uranium mineralization.

DISCUSSION AND CONCLUSIONS

Study of distribution of dissolved radon isotope Rn^{222} in borewell water revealed clusters of anomalies. Besides anomalous radioactivity ranging upto 3 × bgc is also recorded in water of study area. These radioactive expressions in water may be because of high solubility of U, Ra and Rn in water, which facilitates to dissolve these from uranium mineralized rock (Kamlesh Kumar et al. 2010). Follow up reconnoitary drillings have identified the presence of concealed uranium mineralization near to the unconformity plane. This corroborates the fact that the study of ^{222}Rn distribution in borewell water is an effective tool to narrow down the target area for concealed uranium mineralization occurring at shallow depths.

Geo-electrical and electromagnetic surveys conducted in different geological environments in Central India illustrate the efficacy of these methods in deciphering probable subsurface locales of uranium mineralization that are associated with conducting minerals with sulphides, graphites/carbonaceous matter, alteration zones, structural features and shear zones, which have distinct electrical resistivity contrast with respect to host rocks.

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