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Research Article

ENVIRONMENT OF GEOLOGICAL SETTING FOR URANIUM MINERALIZATION AND GEOCHEMICAL EXPLORATION WITH REVIEW FROM CENTRAL INDIA

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ABSTRACT
Survey and exploration in parts of Central India have resulted in the location of numerous occurrences of anomalous concentration of radioactive minerals in various rock types ranging in age from Late Archaean-Paleoproterozoic to Mesozoic. These occurrences are outcome of several episodes of tectonic deformation and associated granitic emplacements, which have provided high geothermal gradient for mobilization and concentration of uranium along shears, fractures and other suitable locales. In addition, these potential rocks make the basement for Meso to Neoproterozoic basins as well as Phanerozoic basins and hence bring ample supply of uranium for its redistribution and localization in favourable environments in younger sediments. Study of distribution of dissolved radon isotope Rn^{222} in borewell water revealed clusters of anomalies. Radioactive expressions in water are because of 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 host rocks.

Keywords: *Geochemical Exploration, Radon (Rn^{222}), VLF-EM Survey, HLEM Survey, Uranium Mineralization, Central India*

INTRODUCTION
The largest and richest uranium deposits are known to have been hosted by Proterozoic rocks (Dahikamp, 1993).The important examples include (a) the unconformity type of uranium deposits occurring in the Athabasca basin, Canada and Pinecreek Geosyncline, Australia (Fogwill, 1981; Needham and Roarty, 1980), (b) the sandstone type of deposits viz, the 0kb uranium deposit, Franciville basin, Gabon and (c) the polymetallic breccia complex type occurring in Olympic dam deposit, South Australia (Sharma *et al.*, 1995).

Uranium is of colossal significance for nuclear and power applications, and its demand is uninterrupted increasing with changing technologies and pace of developments. It is commercially recovered from diverse 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 shown evidences of prolific geological environments and potential for these minerals.

The Chhattisgarh Basin of Bastar Craton in central India has recorded a number of uranium occurrences proximal to the unconformity in the northeastem margin (Bhattacharjee *et al.*, 2005). In this part, uranium mineralisation occurs along the unconformity between the basement granites of Bilaspur-Raigarh-Surguja (BRS) crystallines and the sediments of Chandrapur Group of Chhattisgarh Supergroup at Chitakhol (Sridhar *et al.*, 2007).

Crescent shaped Chbattisgarh basin of Central India occupies an area of about 33,000 km2, and located in parts of Chhattisgarh and Orissa states. It has a maximum length of 300 km. along ENE-WSW direction and a maximum width of 150 Km. in the south central part. The basin is located in the Central Indian shield and forms a part of Bastar craton. Sonakhan greenstone belt in the south, Bilaspur—Raigarh—Surguja (BRS) crystallines in the north, the Sambalpur Granitoids in the East and the N-S trending Kotri Supergroup and Chilpi Group in the west are juxtaposed with the Chhattisgarh sediments (Deshpande *et al.,* 2007). Satpura Gondwana basin is identified as the prime target area for sandstone type of uranium mineralisation.

Recently, the radiometric, regional hydro-geochemical and radon survey have brought out several uraniferous radioactive anomalies associated with tuffaceous sub-feldspathic to feldspathic arenite of Denwa Formation along Jhirpa-Bandhi tract.

These anomalies followed major lineament trending ENE-WSW and occur at the intersection of ENE-WSW, NE-SW and NW-SE trending faults. The lineament passes close to the contact of Lower and Upper Denwa Formation.

The fracture zone extends for over 10km, with width of 200 to 600m. Jam *et al.,* (2007) have discussed the field setting, characterization of uraniferous and nonuraniferous tuffaceous arenite through petro-mineralogical and geochemical means and attempted to establish the nature and control of uranium mineralisation along Thirpa-Bandhi tract of Chhindwara district, Madhya Pradesh.

New model based approach involving multidisciplinary exploration techniques with bias on geophysical and geochemical methods has shown encouraging indication for unconformity related mineralisation and is proximally associated with unconformity between the Palaeoproterozoic basement rocks and the Meso to Neoproterozoic cover sediments.

In the present paper an attempt has been made to discuss about the geological environments under which uranium mineralization has been taken pace in central India (Figure 1).

These geological environments are, namely i) Vein type uranium mineralization, ii) unconforminty -related uranium mineralization, iii) sandstone type uranium mineralization, iv) quartz-pebble conglomerate type uranium mineralization and v) iron oxide-breccia type uranium mineralization. It has also been attempted to argue about the tools of geochemical exploration of uranium mineralization with some earlier presented case studies.

Geological Setting

Central Indian geology disposes rock types as old as >3500 Ma (Older Granitic Gneisses with TTG suite of rocks) to Recent (alluvial placers, clay and laterite). The generalized stratigraphic succession of Central India is given in Table 1.

According to Roy (2007), the Central Indian Precambrian Shield (CIPS) is characterized by Archaean gneisses, granitoids and supracrustal belts, and weakly metamorphosed to Un- metamorphosed volcano-sedimentary and sedimentary cover sequences. This shield region has undergone multiphase tectonic activity, and the predominant Central Indian Suture/Shear zone (CIS) broadly divides it into two domains i.e. 'Bundelkhand Protocontinent' in the north and 'Deccan Protocontinent' in the south (Yedekar *et al.*, 1990, 2000, 2003; Jam *et al.*, 1995).

Extensional tectonics in this region have given rise to several Late Archaean-Proterozoic basins (Figure 1), where older supracrustal belts of Mahakoshal, Betul, Bailadila, Kotri-Dongargarh, Sakoli, represent typical rift characters (Bandyopadhyay *et al.*, 1995; Chakrabarti, 2000; Sarkar, 2000; Acharyya, 2003; Ramachandra *et al.,* 2001; Bhoskar *et al.,* 2004), while younger basins are predominated by platformal sedimentary sequences and represent continental anorogenic environment viz., Abujhmar, Khairagarh, Indravati, Chhattisgarh, Vindhyan, Khariar, Sukma, Pakhal, Sullavai, Ampani etc. (Sarkar, 2000). Some important Proterozoic fold belts are SurgujaBilaspur-Raigarh, Sonakhan and Chilpi (Bhoskar *et al.*, 2004).

In Central India other important rock units are Gondwanas and Deccan Trap with some exposures of infratrappeans.

Gondwana sediments, laid in intracratonic rifled basins, occupy large areas of Central India and accounts for the major coal resources. The infratrappean sediments are laid over basement rocks and capped by Deccan Traps. These are generally restricted to the northern part of Central India and exposed in parts of Jabalpur, Dhar and Thabua districts of Madhya Pradesh. Deccan Trap occupies a major part of Central India and form plateaus and terraces.

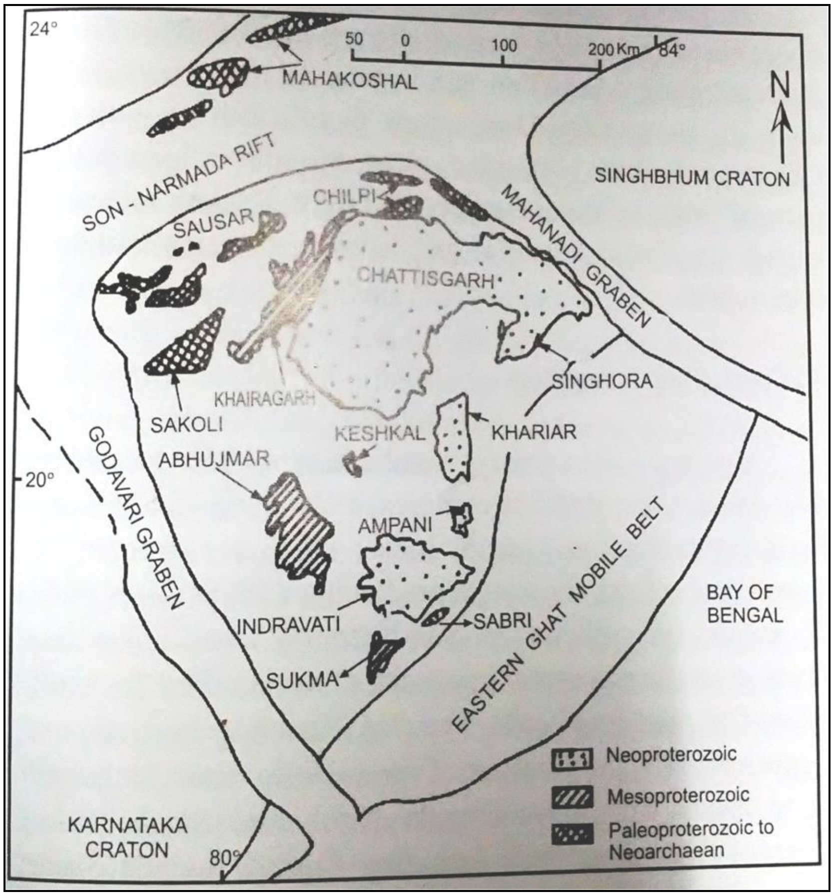

Figure 1: Archaean-Proterozoic basins of Central India (after Roy, 2007)

Uranium Resources

Survey and exploration in parts of Central India have resulted in the location of numerous occurrences of anomalous concentration of radioactive minerals in various rock types ranging in age from Late Archaean-Paleoproterozoic to Mesozoic (Roy, 2007).

These occurrences are outcome of several episodes of tectonic deformation and associated granitic emplacements, which have provided high geothermal gradient for mobilization and concentration of uranium along shears, fractures and other suitable locales.

In addition, these potential rocks make the basement for Meso to Neoproterozoic basins as well as Phanerozoic basins and hence bring ample supply of uranium for its redistribution and localization in favourable environments in younger sediments.

From uranium mineralization point of view, Central India can be broadly grouped into three major stratigraphic domains viz., i) Archaean to Paleoproterozoic crystallines (Basement rock), ii) Meso to Neoproterozoic sedimentary basins, and iii) Phanerozoic sedimentary basins. A short description of significant deposits and occurrences are given in following paragraphs.

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Table 1: Generalised stratigraphic succession of Central India (modified after Sarkar, 1980; Naqvi and Rogers, 1987; Sarkar *et al.*, 1990; Bandyopadhyay *et al.*, 1990; Mishra, 2004; Ray, 2006, c.f. Roy, 2007)

Age	Supergroup/Group	Significant Economic Mineral Association
Pleistoicene to Recent (2,3 Ma to Present)		Placer & alluvial deposits of ilmenite, Magnetite, Ag-Au, Y.Th and latgertic bauxite
Up. Cretaceous to Eocdene (90-60 Ma)	Deccan Trap Infratrappeans	Limestone, zeolites, calcite, native Cu, U Coal and coal bed methane, U, Th
L.Carbho9nife4rous to L.Cretaceous (300-120 Ma)	Gondwana Ssupergroup	
Meso to Neoproterozoic (1600-542 Ma)	Sabnri Gropup (Sukma basin) Indravati Group Chhattisgarh Supergroup Vindhyan Supergroup	Limestone, dolomite, barites, fluorite, Diamond, U.Th.
Mesoproterozoic (1600-900 Ma)	Khairagarh Group, Chilpi Group, Gawalior Group	U, Th, Mn, Cu
Neoarchean to Paleoproterozoic (2500-1600 Ma)	Sausar Group, Abujhmar Group Nandgaon Group, Sakoli Group, Sonakhan Group, Bijawar Group, Dongargarh Granaites	Mn,U,Th,Au,Ag,Nb,Ta
Neoarchean (2900-2500 Ma)	Bundelkhand Granites, Bailadila Group, Mahakoshals, Bengpal, Amgaon and Sukma supracrustals	Fe,Cu,Pb,Zn,U,Th,Sn,W,Nb-Ta
Mesoarchean (3500-2900 Ma)	Older Granitic Gneisses with TTG Suite of rocks, migmatites, unclassified Crystallinesw with ultramafric, mafic and felsic intrusive.	Fe,V,Ti,Cr,Mg,Ba,F,W,Au,Ag,Cu,Ni,Co,U

Vein Type Uranium Mineralisation

In Central India vein type of uranium deposit and occurrences have been located along Central Surguja Shear Zone affecting crystallines and in bimodal volcano-plutonic complex along Kotri-Dongargarh mobile belt in parts of Chhattisgarh State. Besides, older crystallines exposed in parts of Sidhi and Betul districts of Madhya Pradesh have also shown significant potential and incorporate some uranium occurrences.

Vein type of uranium mineralisation has been located in three important crystalline complexes viz., Surguja, Sidhi and Betul crystallines in Central India (Table 2), which are exposed as narrow linear belts showing a predominant ENE-WSW to EW trends sympathetic to Son-Narmada-Tapti lineament. These crystalline complexes consist of unclassified gneisses, migmatites and granitoids. The Son-Narmada-Tapti zone is characterized by the presence of several lineaments, faults and shear zones viz., Son-

Narmada North and South faults, Tatapani-Balrampur fault including Central Surguja Shear Zone, Gavilgarh fault, Khadwa lineament, Tan shear and Central India Suture Zone. In addition, the northern extensions of Peninsular Gneissic Complex in parts of Nanded district have also shown potential for uranium mineralisation. Among the above mentioned crystalline complexes, Surguja crystallines have the highest potential for uranium mineralisation.

Table 2: Distribution of uranium occurrences in Central India through geological time (after Roy, 2007)

Upper Cretaceous (Infratrappean)	Sandstone (Chert)	Lalbarra (Mandla dist., M.P.), Dholiya, Sukar and Temriya (Dhar district, M.P.)
Lower Cretacous to Upper Carboniferous (Gondwana)	Sandstone	Kharatoriya (Chhindwara district, M.P.) Bhawra (Betul dist., M.P.), Polapathar (Hosangabad district, M.P.)
	Vein	Bodal, Bhandaritola, Jangalpur, Bagnadi (Rajnandgaon district, C.G.), Shirmal (Mahasamund district, CG.)
Neoproterozoie to Mesoproterozoic	Sandstone/ Unconformity related	Mogarra, Malharbodi, Makardhokra, Nalpani, Udrichhapar (Rajnandgaon district, CG.), Juba, Mahasamund district,
	Unconformity related	Kerali, Waler, Bogan (Bastar district, CG.) Darba, Silekjhodi, Chandragiri (Bastar district, CG.),
Paleoproterozoic to Archaean Vein type	Vein	Chitakhol (Korba-Janjgir district, CG.), Damdama (Raigarh district, CG.) Baskati, Khurmucha (Sidhi district, M.P.) Jajawal, Dumhat, Dhabi, Jhor-Jhirat, Jhapar-Baran River (Surguja district, CG.), Banjarinmata, Bispur (Bastar district, CG.),
	Iron-oxide breccias	Dulapali (Raigarh district, CG.) Ban, Meraraich, (Sidhi district, M.P.),
	Quartz-pebble conglomerate	Sonaghati (Betul district, M.P.) Shahpur, Sujayatpur (Nanded district, MS.) Otavna (Sindhudurg district, MS.) Bhuski (Rajnandgaon district, CG.) Gotulmura (Durg district, CG.)

Unconformity-Related Uranium Mineralisation

Meso and Neoproterozoic basins of Central India *viz*., Abujhmar, Indravati, Khairagarh, Chhattisgarh, Vindhyan etc. provide ideal set up for unconformity related uranium mineralization. These basins have formed in anorogenic environment and are related to extensional tectonics. Basement for these Proterozoic basins are ArchaeanPaleoproterozoic crystallines, bimodal volcanics or metasediments, which also form fertile provenance for uranium. In this set up, tectonic reactivation plays significant role in mobilization and enrichment of uranium in suitable traps either along unconformity or just below or above the unconformity as well as along fracture zones. A large number of uranium occurrences have been located in these favourable setting of unconformity type uranium mineralisation in almost all Proterozoic basins of Central India. These are only indicative of possibilities of unconformity type uranium deposit in a basin, though many of them resemble strata-bound sandstone type mineralisation also.

Sandstone Type Uranium Mineralisation

Ideal sandstone type uranium mineralization is generally associated with Mesozoic and younger sediments, where geochemical conditions especially the redox interfaces play a vital role for fixation of uranium.

However, Phanerozoic basins, such as Gondwana, also provide a favourable setup for this type of uranium mineralisation in Central India. Gondwana basins occur as long linear belts within intracratonic rifts amidst Archaean-Proterozoic platformal segments.

Basement rocks for Gondwana sediments provide substantial quantity of uranium for remobilization. In fact, these older rocks are generally fertile in nature with anomalous uranium content, which got significantly enhanced during multiple episodes of deformation and teactivation including emplacement of younger evolved granites. Remobilized uranium from basement as well as sediments gets deposited under favourable geochemical conditions in suitable traps in Gondwanas. Generally, gently dipping sandstone beds with suitable reductant and sandwiched by impervious shale horizons are ideal for sandstone type of uranium mineralisation.

Quartz-Pebble Conglomerate Type Uranium Mineralisation

These are the oldest sedimentary uranium mineralisation formed as palaeoplacer in euxinic condition prevailing on earth prior to 2200 my. Quartz-pebble conglomerate type uranium mineralisation is generally associated with Neoarchaean-Paleoproterozoic unconformity and is bounded by banded iron formations.

Their relationship with iron-formations is an important guideline in search of QPC type of mineralisation. This type of set up is present in Central India in Bastar craton where oligomictic quartz-pebble conglomerate associated with quartz chlorite schist is present at the base of Bailadila Group in the vicinity of Kotri-Dongargarh mobile belt.

First uranium occurrence of quartz-pebble conglomerate type in Central India has been recently discovered over a 9 km long zone at Gotulmura (up to 0.16% U_30_8), south of Dalli Rajhara, Durg district, Chhattisgarh. Radioactivity is due to presence ofuraninite besides monazite and xenotime.

Iron Oxide Breccia Type Uranium Mineralisation

Iron oxide breccia (lOB) type of uranium mineralisation is characterized by their close proximity to iron formations and formed during anorogenic extensional tectonic regime with lot of ultramafic extrusions. This type of set up is available along Kotri-Dongargarh belt, Sakoli basin and adjoining areas in Central India which are located close to Banded Iron Formation of Bailadila Group having NW-SE disposition and marked by a fault zone (Rajagopalan and Hansoti, 1997).

A number of ultramafic bodies are also present. This zone has also undergone multiple episodes of tectonic disturbances and reactivations.

Uranium occurrence of IOB type mineralisation has been recorded in Patkasa Formation of Kotri Supergroup at Bhuski (up to 0.039% U_30_5), Kanker district, Chhattisgarh (Choudhury *et al.,* 1999). Uranium mineralisation is hosted by ferruginous breccia within sandstone juxtaposed with BIF. Uranium mineralisation is related to fen-uginisation, preceded by evolving hydrothermal fluids during bimodal plutonovolcanism in Kotri rift zone. Similar mineralisation could be expected in southem margin of Vindhyan basin at its contact with Sidhi crystallines and Mahakoshal Group of rocks in Sidhi district, MR and in Khairagarh basin (Roy, 2007).

Geochemical Exploration

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 colorless, odorless, 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 *et al.*, 2007).

Radon is 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 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}gm is expected to be more from the rock having more intrinsic uranium like granites, pegmatites and uranium mineralised 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 *et al.*, 2010).

Indravati basin, having an area of 9000km^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. These borewells are located in three sectors of Indravati Basin. The radon counts (^{222}Rn) ranges 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).

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 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 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.

Thus the resistivity map thus generated pointed put three prominent low resistivity zones. 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 the one of the zone 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 of 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 and 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.

RESULTS AND DISCUSSION???

Discussion and Conclusions

Central Indian geology disposes rock types as old as >3500 Ma to Recent. The Central Indian Precambrian Shield (CIPS) is characterized by Archaean gneisses, granitoids and supracrustal belts, and weakly metamorphosed to Un- metamorphosed volcano-sedimentary and sedimentary cover sequences. This shield region has undergone multiphase tectonic activity, and the predominant Central Indian Suture/Shear zone (CIS) broadly divides it into two domains i.e. 'Bundelkhand Protocontinent' in the north and 'Deccan Protocontinent' in the south. In Central India other important rock units are Gondwanas and Deccan Trap with some exposures of infratrappeans.
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Ideal sandstone type uranium mineralization is generally associated with Mesozoic and younger sediments, where geochemical conditions especially the redox interfaces play a vital role for fixation of uranium. However, Phanerozoic basins, such as Gondwana, also provide a favourable setup for this type of uranium mineralisation in Central India. Gondwana basins occur as long linear belts within intracratonic rifts amidst Archaean-Proterozoic platformal segments. Basement rocks for Gondwana sediments provide substantial quantity of uranium for remobilization. In fact, these older rocks are generally fertile in nature with anomalous uranium content, which got significantly enhanced during multiple episodes of deformation and teactivation including emplacement of younger evolved granites. Remobilized uranium from basement as well as sediments gets deposited under favourable geochemical conditions in suitable traps in Gondwanas. The oldest sedimentary uranium mineralisation formed as palaeoplacer in euxinic condition prevailing on earth prior to 2200 my. Quartz-pebble conglomerate type uranium mineralisation is generally associated with Neoarchaean-Paleoproterozoic unconformity and is bounded by banded iron formations. Their relationship with iron-formations is an important guideline in search of QPC type of mineralisation. This type of set up is present in Central India in Bastar craton where oligomictic quartz-pebble conglomerate associated with quartz chlorite schist is present at the base of Bailadila Group in the vicinity of Kotri-Dongargarh mobile belt.

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This zone has also undergone multiple episodes of tectonic disturbances and reactivations.

Study of distribution of dissolved radon isotope Rn^{222} in borewell water revealed clusters of anomalies. Besides anomalous radioactivity ranging up to 3 x 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 *et al.*, 2007). Follow up reconnoitary drillings have identified presence of concealed uranium mineralization near to the unconformity plane. This corroborates to 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 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 host rocks.

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