Radioelemental distribution in Neoproterozoic volcano-sedimentary Sindreth Basin, Sirohi District, Rajasthan and its significance

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The U/Th ratios in rocks of the Neoproterozoic volcano-sedimentary Sindreth Basin and its surroundings represented by Erinpura Granite/Migmatite and Mesoproterozoic Sirohi metasedimentary rocks occurring at Sindreth, Sirohi District, Rajasthan, have been studied. The felsic rocks occurring in the western part of the basin are marked by low U/Th ratios. The rocks of Sirohi Group and the Erinpura Granite also show low U/Th ratio which indicates removal or depletion of uranium. The polymictic conglomerate and basic rock in the eastern margin of the Sindreth Basin show significantly higher U/Th ratios suggesting enrichment of uranium due to remobilization and the resultant uranium mineralization (U_3O_8 values 0.014–0.098 and ThO_2 < 0.01%) associated with alterations, viz. limonitization, chloritization, haematitization, silicification and sericitization. U-mineralization in the Sindreth Basin is a new find and is of volcanogenic-type.

Keywords: Felsic rocks, radioelemental distribution, uranium mineralization, volcano-sedimentary basin.

THE Sindreth Group represents an isolated volcano-sedimentary sequence which occurs along the western flank of the Proterozoic Delhi Fold Belt in Rajasthan[1]. It is exposed in an elongated shape over an area of about 40 sq. km. Outliers of rock units similar to those of the Sindreth Group occur within the Delhi Supergroup of rocks up to 10 km southwest of the southern edge of the main Sindreth outcrop area[2]. The Sindreth Group comprises a repetitive sequence of bimodal volcanic rocks along with coarse clastics and volcaniclastic rocks. It represents a Neoproterozoic volcano-sedimentary sequence interpreted as deposits of molasses that accumulated in the post-Delhi orogeny successor basin. The Sindreth basin is approximately parallel to the Aravalli orographic axis and is a N–S to NE–SW trending, linear, isolated sedimentary basin, exposed within a granitic terrane. The Sindreth Group unconformably overlies the Sirohi Group which comprises a thick sequence of argillaceous sedimentary rocks with minor arenaceous intercalations. The latter are associated with ultramafic rocks and constitute flysch-type sedimentary rocks of the South Delhi belt. They are complexly folded and extensively intruded by the syn- to late-kinematic Erinpura Granite (EG). The thickness of the Sindreth Group is approximately 500 m. It has been subdivided into the Khambal and Angor formations. The unconformable relationship between the EG and the Khambal Formation is represented by the basal polymictic conglomerate. The Khambal Formation also contains basalts, siltstone, chert and tuff. The Angor Formation contains basic and felsic volcanic rocks, ash-flow tuff, ignimbrite and polymictic conglomerate. NNW–SSE and N–S trending dolerite dykes have intruded the Sirohi Group and Sindreth Group of rocks as well as the EG, and follow the same trend as the felsic dykes that have been correlated with the terminal phases of the Malani Igneous Suite. This ensemble of bimodal volcanic and sedimentary rocks shows a general N–S trend with moderate westerly dips[1]. U–Pb zircon ages for the Sindreth Group rhyolite are 767 ± 2.9 Ma. Ages for rhyolites from the Angor Formation[3] are 765.9 ± 1.6 Ma and 761 ± 16 Ma. Felsic volcanic rocks (rhyolite, dacite) interlayered with the Sindreth basalts have yielded ages between 761 ± 16 Ma and 767 ± 3 Ma, which have been interpreted as representing the time of primary magmatic activity[3]. Mafic tonalite from post-Delhi granites yield U–Pb ages of 800 ± 2.4 Ma and 873 ± 2.6 Ma, which have been correlated with the post-Delhi EGs[3]. The Sindreth area is characterized by three different geological environments comprising the Sindreth Basin (conglomerate, felsic and mafic rocks and quartz porphyry) the Sirohi Group (phyllite and dolomite) and the EG/Migmatite (Figure 1).

One hundred and fourteen samples drawn from different rock formations were analysed for U (Ra eq) and Th. Because there is not much disequilibrium in the uranium series, for all practical purposes, Ra eq U values are represented as U values in the laboratory data. U (Ra eq)/Th ratios were studied to understand the mobility of uranium in different rock types. The ranges of U/Th in each rock type are summarized in Table 1.

The data indicate that the U/Th ratios in basic rock are higher (up to 4.25) with an average of 0.99, whereas the reported average of ratio based on intrinsic contents of U and Th in basic rock is 0.2. Similarly, the conglomerate also shows higher U/Th ratio (up to 2.89) with an average 0.85, whereas the reported average of ratio based on intrinsic contents of U and Th in the conglomerate is 0.3. These higher U/Th ratios in basic rock and conglomerate were seen to be present on the southern tip of the hill near Sindreth village. On the other hand, the average U/Th ratio is lower for quartz porphyry, phyllite, cherty dolomite, granite and felsic volcanic rocks, compared to their reported average ratios based on their intrinsic values in these rocks as given in Table 1. These data indicate remobilization of uranium in the volcano-sedimentary Sindreth Basin.

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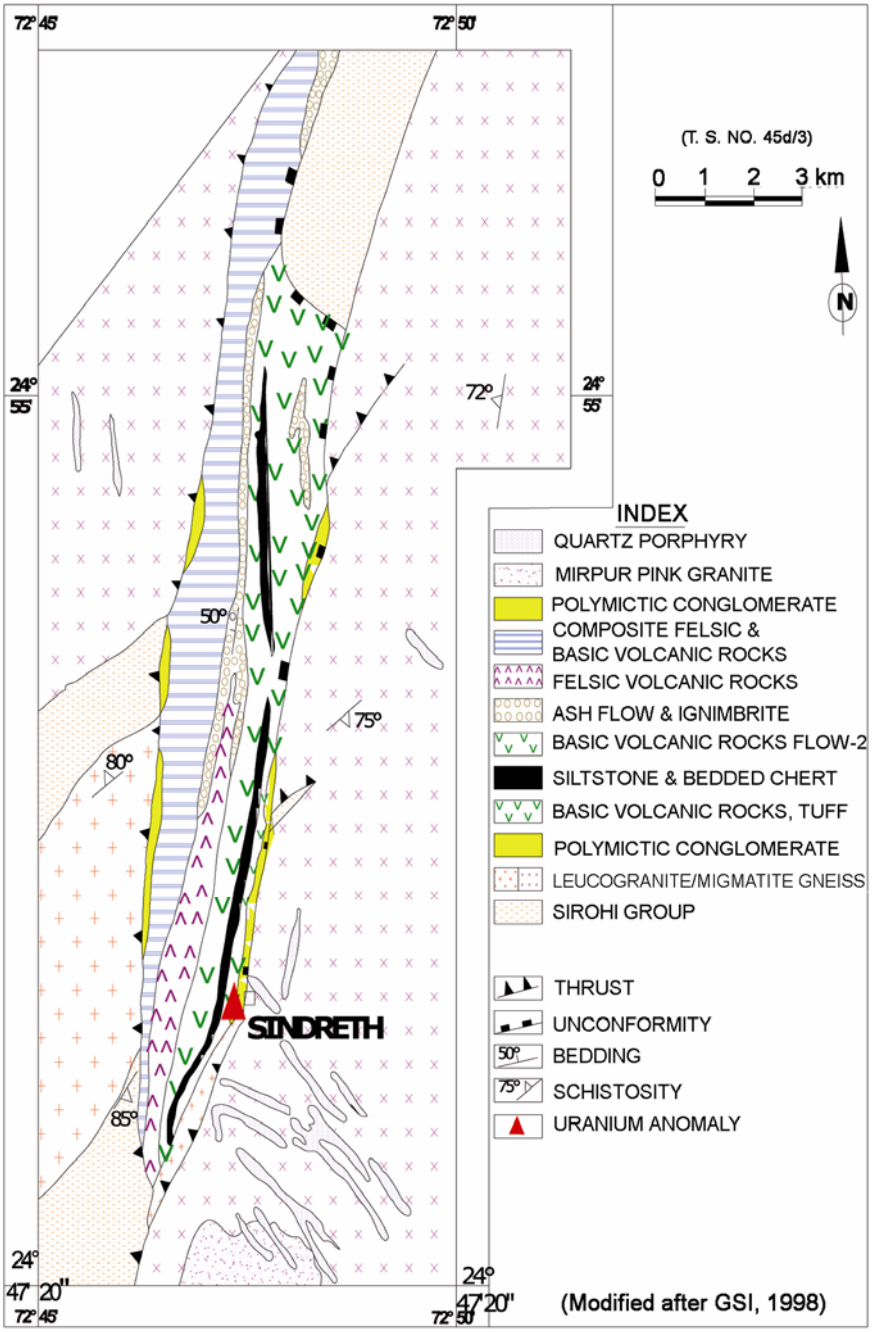

Figure 1. Geological map of Sindreth Basin, Sirohi District, Rajasthan.

Table 1. U/Th ratios in different rock types around Sindreth area

Rock	U_3O_8 (Ra eq; ppm)	ThO_2 (ppm)	Range of U/Th ratios	U/Th ratio of field samples	Average U/Th ratio[5]
Quartz porphyry (n = 21)	2–12	20–83	0.05–0.32	0.15	0.3
Phyllite (n = 19)	2–67	5–51	0.10–0.48	0.19	0.25
Cherty dolomite (n = 3)	2–7	5–12	0.44–0.56	0.49	0.6–1.5
Granite (n = 22)	2–16	5–87	0.03–0.52	0.21	0.3
Felsic volcanic rocks (tuff/rhyolite) (n = 26)	2–12	5–85	0.08–0.48	0.21	0.3
Conglomerate (n = 8)	2–48	5–18	0.22–2.89	0.85	0.3
Basic rock (n = 15)	2–22	5–20	0.12–4.25	0.99	0.2

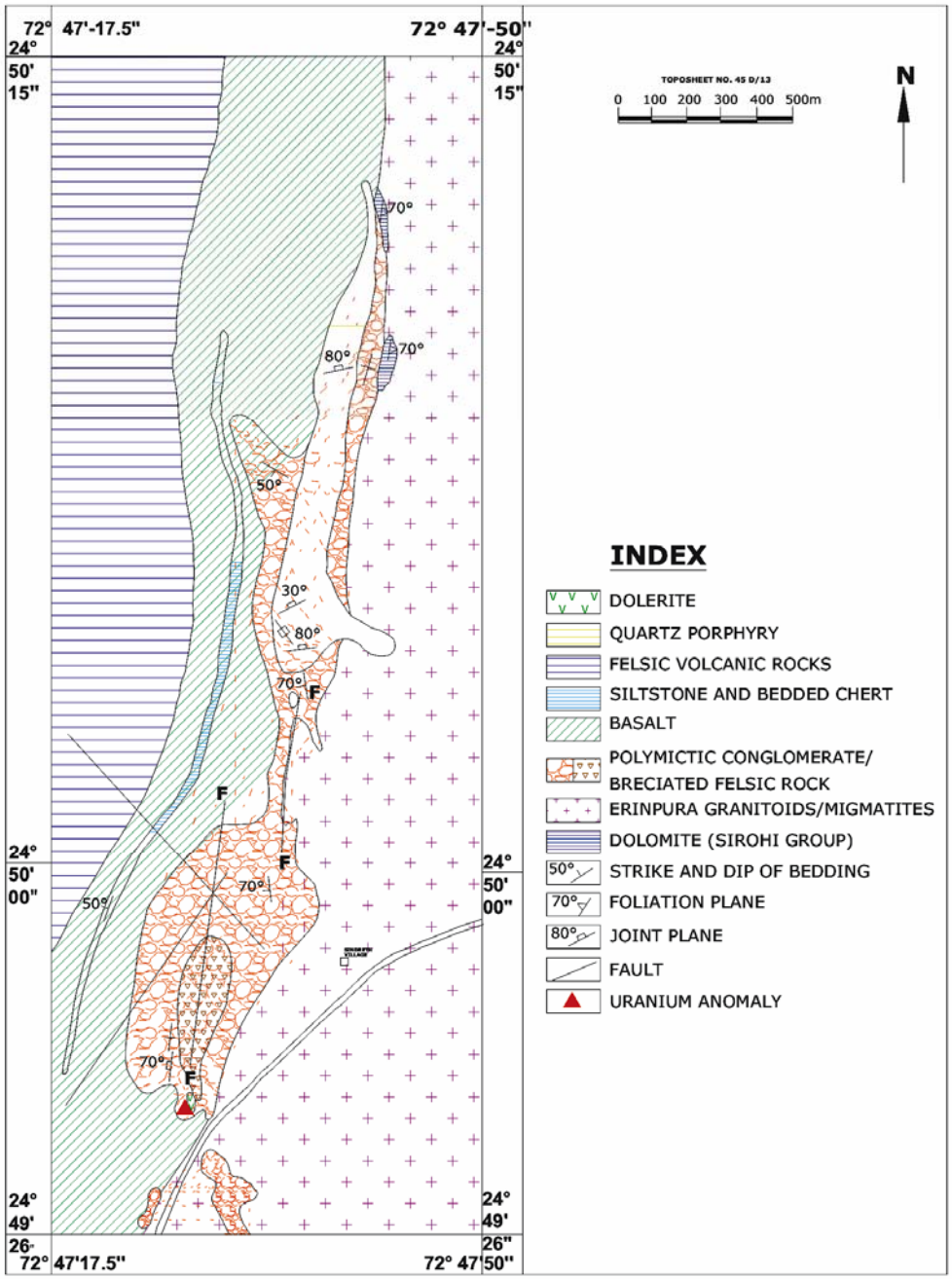

Figure 2. Geological map of Sindreth area Sindreth Basin, Sirohi District, Rajasthan.

Detailed studies in the zone of higher U/Th ratios near Sindreth village were conducted. A thick sequence of polymictic conglomerate is exposed in this area, which lies directly in contact with the post-Delhi EG. The conglomerate here is very coarse, highly unsorted, containing angular, sub-rounded and rounded pebbles and boulders of predominantly quartzite and quartz. The majority of the clasts are in the size range 0.5–20 cm. Uranium mineralization is observed at the southernmost tip of the conglomerate hill confined to lower contours (Figure 2). Detailed geological examination of the area has revealed the presence of very coarse polymictic conglomerate in contact with gritty rock in the west, which is in turn in contact with basalt flow-1.

In this area, there are a few patches of highly altered basic rock and polymictic conglomerate showing N–S trend (Figure 3). Gross gamma radiation survey was carried out in this zone using 1¾″ × 2″ NaI(Tl) crystal-based portable gamma ray spectrometer (PGRS), designed and fabricated by the Atomic Minerals Directorate for Exploration and Research (AMD), Hyderabad. This instrument is primarily designed for differentiating uranium

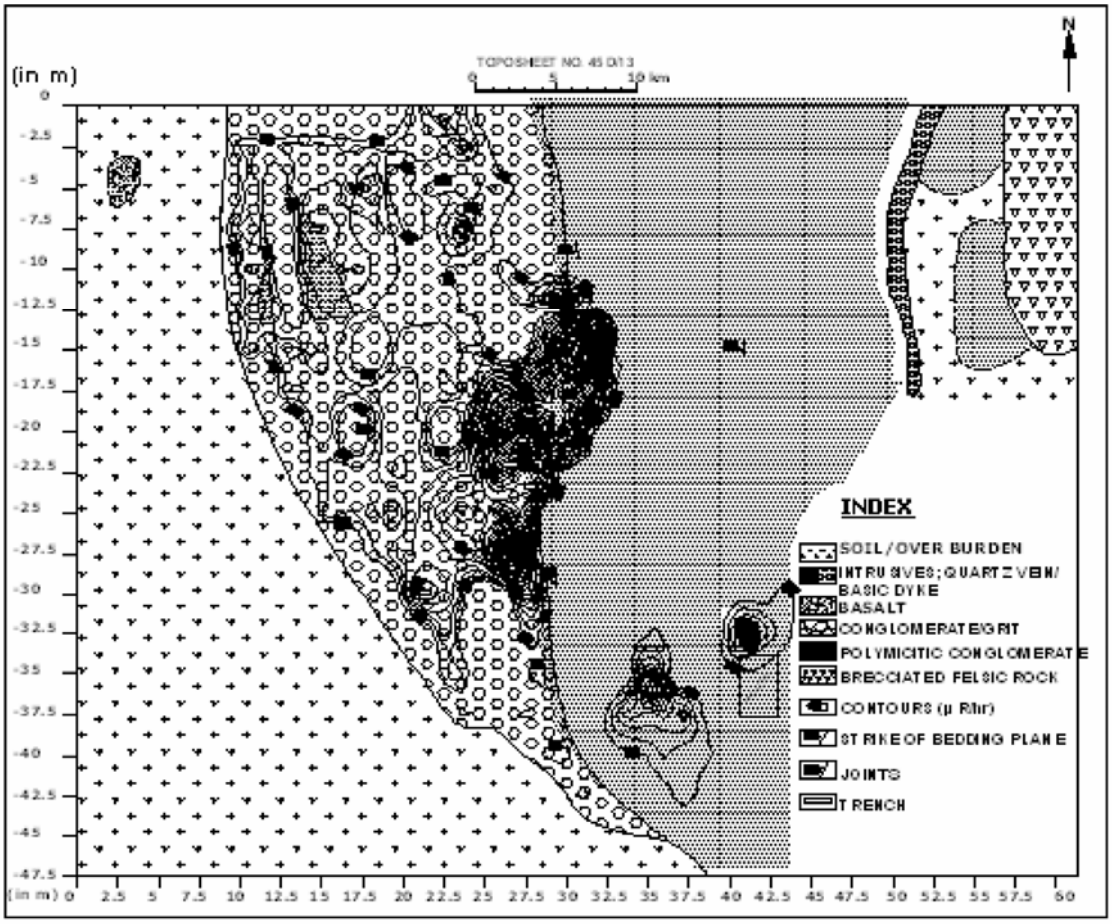

Figure 3. Geological and Isorad map of Sindreth Uranium anomaly, Sirohi District, Rajasthan.

Table 2. Radiometric analysis of radioactive samples

Sample no.	Rock	e U_3O_8 (%)	U_3O_8 (%)	ThO_2 (%)	*K* (%)
SND/E	Altered basic rock	0.035	0.036	< 0.01	3.7
SND/W	Altered basic rock	0.086	0.098	< 0.01	3.7
SND/C/CM	Altered basic rock	0.070	0.093	< 0.01	2.4
SND/C/CL	Altered basic rock	0.027	0.030	< 0.01	2.9
SND/CG/W3	Conglomerate	0.013	0.014	< 0.01	2.4
SND/CEB/1	Conglomerate	0.014	0.014	< 0.01	0.6
SND/CNG/14	Conglomerate	0.019	0.033	< 0.010	< 0.5
SND/CNG/9	Conglomerate	0.014	0.027	< 0.010	0.9
SND/CNG/7	Conglomerate	0.026	0.036	< 0.010	3.2
SND/CNG/5	Conglomerate	0.012	0.019	< 0.010	1.9

Table 3. Chemical analysis of mineralized samples from Sindreth (all data in ppm)

Sample no.	Rock	La	Ce	Nd	Pr	Sm	REE (T)	Sc	Y	U_3O_8	Pb	V	Cu
SND/E	Altered basic rock	30	135	53	5	14	237	25	75	318	60	257	89
SND/W	Altered basic rock	31	220	68	12	15	346	19	60	752	178	300	55
SND/C/CM	Altered basic rock	29	167	57	5	13	271	21	59	660	165	235	32
SND/CG/W3	Conglomerate	17	70	38	5	2.5	132.5	4	27	106	15	84	13
SND/CEB/1	Conglomerate	19	64	21	5	2.5	111.5	–	29	124	28	100	16
SND/CNG/7	Conglomerate	NA	NA	NA	NA	NA	NA	NA	NA	360	115	176	18
SND/CNG/5	Conglomerate	NA	NA	NA	NA	NA	NA	NA	NA	190	33	77	33

NA, Not analysed.

and thorium when operated in spectrometric mode; however, the same instrument can also be used in integral mode for *in situ* gross gamma radiation counts. These counts were recorded using a grid pattern of 0.5 m × 2.5 m over an area of 2500 sq. m, in the zone of intense alteration. The clusters of higher counts (in micro roentgen/h) were marked as shown in Figure 3. It was observed that higher counts were confined to areas where the basic rock occurs. Also, the highest counts were recorded at the contact of polymictic conglomerate and gritty rock in conjunction with basic rock possibly indicating a weak zone.

Features of brecciation are distinctly observed in N–S trending quartz porphyry dyke lying northeast of the mineralized area suggesting the role of faulting in localizing uranium (Figure 2). This quartz porphyry dyke is emplaced within the polymictic conglomerate. Minor but indistinct signs of brecciation are also seen in the basic dyke exposed to the west of the quartz porphyry dyke.

Radiometric analysis of samples collected from the Sindreth altered rock zone is given in Table 2.

Geochemically, the uranium mineralized rocks are enriched in rare earth elements (REE), Pb and V (Table 3). The correlation coefficients calculated for U_3O_8 versus REE (total), Pb, Ce and V show strong positive correlation of 0.95, 0.97, 0.96 and 0.86 respectively, indicating enrichment of uranium and of these elements as a coeval event, possibly due to hydrothermal solution activity.

U/Th ratios are indicators of mobility and the concentration of uranium in a geological system. A study of these ratios in the area has so far shown that the conglomerate and basic rock acted as hosts for uranium mineralization and these rocks show elevated values compared to average values, whereas rocks such as granite, felsic rocks and phyllites show lower U/Th ratios indicating remobilization of uranium from these rocks.

The volcanogenic-type uranium deposits are known in many parts of the world, viz. Streltsvokye-Antei, Russia; Dornot, Mongolia and McDermitt, USA[4]. In this context, uranium mineralization reported in Neoproterozoic volcano-sedimentary Sindreth Basin appears to be very significant and it has opened up a new geological domain for the uranium exploration in southwestern Rajasthan.

The initial data collected from the Sindreth uranium-mineralized area are encouraging. However, no uranium mineral has been observed so far in the samples. The alpha tracks of mineralized samples reveal dispersed nature of uranium which could result due to the highly oxidized nature of rocks on and near the surface. At depth, below the zone of oxidization, there is probability of finding discrete uranium minerals.

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Seed predators of an old-world tropical deciduous tree (*Terminalia bellirica*: Combretaceae) in wet habitats of the Western Ghats, India

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In this study I assess the diversity of seed predators, intensity of seed predation, germination success and survival of germinated cotyledons of an old-world tropical deciduous tree (*Terminalia bellirica*) in wet habitats of the Western Ghats biodiversity hotspot. Primary arboreal seed predators were Malabar giant squirrel (*Ratufa indica*) in evergreen forests and an unidentified weevil species (Curculionidae: Coleoptera) in wet evergreen forests and coffee agroforests. Kernel predation by weevils was higher in coffee agroforests (43.7%) compared to wet evergreen forests (25%). In both habitats, two terrestrial rodents, the Malabar Spiny Dormouse (*Platacanthomys lasiurus*) and an unidentified rat species (*Rattus* sp.) were the primary seed predators on the ground. Herbivory by ants resulted in low survival of germinated cotyledons in both habitats. Ants consumed a greater amount of germinated cotyledons in coffee agroforests compared to evergreen forests.

Keywords: *Ratufa indica*, seed predation, *Terminalia bellirica*, tropical plants, wet habitats.

IN tropical climates, seeds of most wild plants have to undergo a series of events that may affect the natural recruitment[1]. This includes pollination, seed dispersal,

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