Uranium mineralization in Talchir Formation of Gondwana Supergroup, Surguja District, Chhattisgarh

Sandstone-hosted uranium deposits of Gondwana age in the Beaufort Group of Karoo Basin, South Africa and Callinga-staupstata Basin, Sierra Pintada, Argentina are well known[1]. Some uranium deposits are associated with Phanerozoic unconformity and faults dissecting basement and sediments, such as Bertholene and Le Roube, Aveyron, France, where Permo–Carboniferous clastic sediments with some volcanic components rest on Proterozoic schists and gneisses[2]. In India, Motur sandstone (Permian) samples of Satpura basin have been analysed (0.015–0.34% U_3O_8 and 0.014–0.10% ThO_2) (ref. 3). Panchamari and Denwa arenite of Satpura basin (Upper Gondwana) have been analysed (0.018–0.11% U_3O_8 and <0.010 ThO_2) (refs 4 and 5). During 2009–2010, then we studied the Lower Gondwana sediments of Ramkola–Tatapani sub-basin in Surguja District, Chhattisgarh and discovered uranium mineralization in feldspathic sandstone and basal conglomerate of the Talchir Formation (Figure 1).

Talchir Formation, the lowermost part of the Gondwana Supergroup, exposed along Mahan river, unconformably overlies the Precambrian basement of Surguja crystalline rocks. The basal part of the Talchir Formation comprises conglomerate commonly referred to as 'Talchir boulder bed'. It is overlain by feldspathic sandstone and shale deposited in open self environment[6]. The trend of the Talchir Formation is ESE–WNW to E–W. The beds are sub-horizontal and show low dip due north or south in the eastern part, near Alakhdiha, Ginwar, Munuva and Karwan, Surguja District. ESE–WNW, ENE–WSW, E–W, NW–SE and N–S trending fractures are frequent and prominent in the Gondwana sedimentary rocks. The Talchir Formation is overlain by coal-bearing fluviatile succession of the Barakar Formation, which occupies most of the western area (Figure 1) and is represented by whitish-grey to greyish-white, medium to coarse-grained, micaceous, feldspathic, massive to cross-bedded sandstone, black shale and coal-bearing sandstone. All these are capped by laterites. The generalized stratigraphic succession of the study area is given in Table 1.

Studies have revealed uranium mineralization in two litho-units of the Talchir Formation, i.e. (i) basal conglomerates near Ginwar and (ii) feldspathic sandstone near Munuva, Karwan and Alakhdiha (Survey of India topographic sheet no. 64M/7; Figure 1). Mineralized

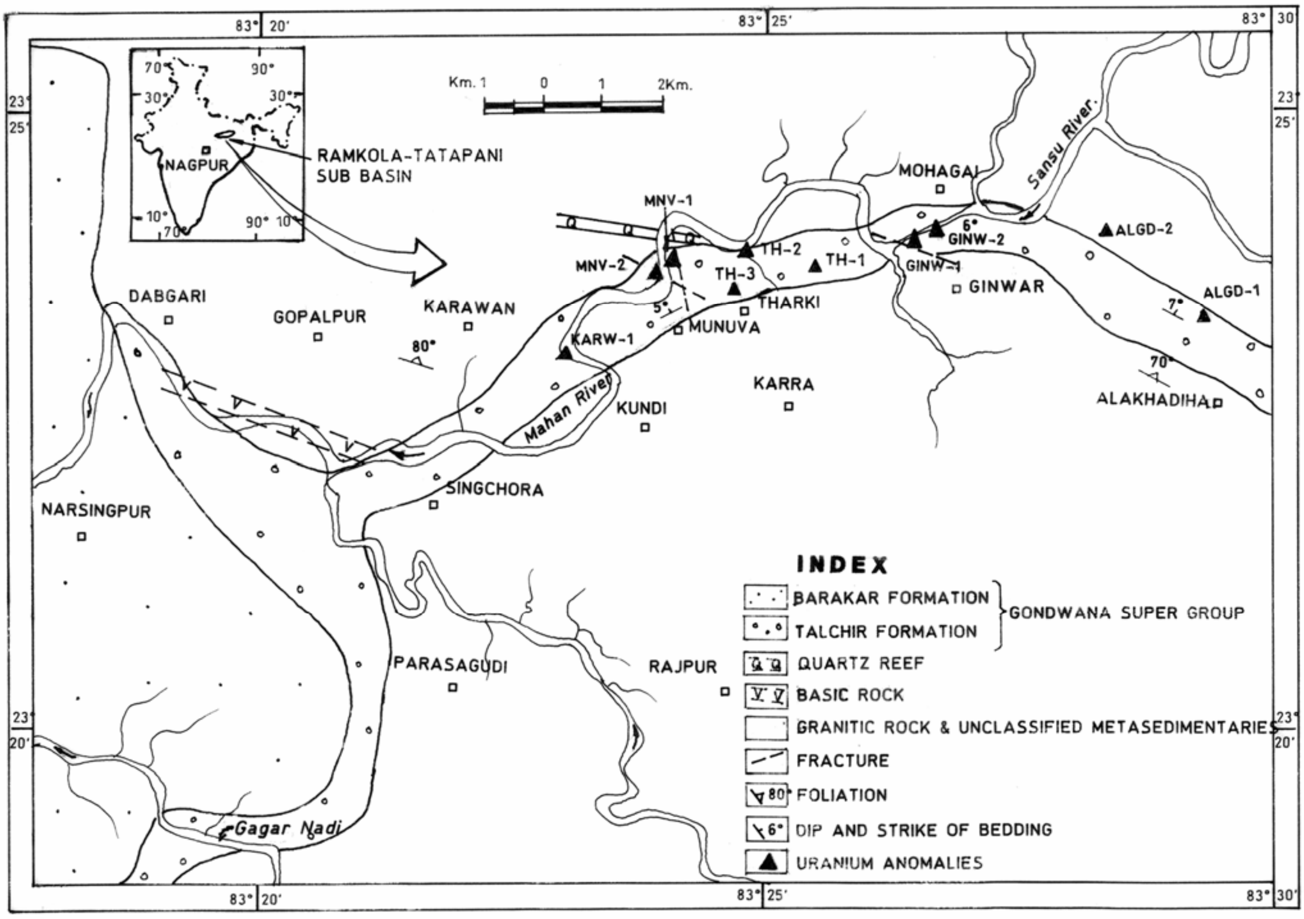

Figure 1. Geological map showing uranium mineralization in Karwan–Munuva–Ginwar, Surguja District, Chhattisgarh.

Table 1. Generalized stratigraphic succession of the study area

Stratigraphic age	Stratigraphic position		Rock type
Pleistocene to Recent	Laterites and brown soil		
Upper Carboniferous to Permian	Gondwana Supergroup	Barakar Formation Talchir Formation	Coal-bearing sandstone and shale Boulder bed, sandstone and shale
Lower to Middle Proterozoic	Grey foliated granite (1392 ma) Gneissic complex: biotite–gneiss, plagioclase–biotite–gneiss and migmatite		
Archaean	Amphibolites, quartzite, muscovite–sericite–schist, biotite–chlorite schist and calc-gneiss		

Table 2. Physical assay result of radioactive samples of Gondwana sediments, Surguja District, Chhattisgarh

Anomaly number and number of samples	Locality and coordinates	Host rock and stratigraphic position	Dimension (length × width) (m)	eU_3O_8 (%)	U_3O_8 (β/γ) (%)	ThO_2 (%)
MNV-1 (n = 6)	North of Munuva close to Mahan river 23°23′41.9″–23°23′42.8″N 83°23′54.7″–83°23′55.0″E	Talchir sandstone, along N–S fracture	65 × 1–5	0.013–0.18 (avg = 0.048)	0.015–0.16 (avg = 0.043)	<0.005
MNV-2 (n = 3)	North of Munuva/north of Kundi Mahan riverbed 23°23′38.5″–23°23′39.9″N 83°23′48.9″–83°23′50.6″E	Talchir sandstone, along NW–SE fracture	45 × 0.50	0.011–0.032 (avg = 0.020)	0.012–0.032 (avg = 0.021)	<0.005
MNV-3 (n = 2)	North of Munuva/north of Kundi Mahan riverbed 23°23′39.0″N, 83°23′48.1″E	Talchir sandstone	5 × 0.50	0.019–0.020 (avg = 0.019)	0.020–0.021 (avg = 0.021)	<0.005
KARW-1 (n = 4)	East of Karwan along Mahan riverbed 23°23′03.6″N, 83°22′55.2″E	Talchir sandstone	11 × 0.50–1.00	<0.010–0.016 (avg = 0.013)	<0.010–0.021 (avg = 0.016)	<0.005
ALGD-1 (n = 3)	Near Alakhdiha village 23°23′14.5″N, 83°29′16.6″E	Talchir sandstone	1 × 0.5	0.011–0.017 (avg = 0.014)	0.013–0.016 (avg = 0.014)	<0.005
GINW-1 (n = 8)	North of Ginwar/southern bank of Mahan river 23°23′57.4″–23°23′58.0″N 83°26′22.6″–83°26′29.0″E	Talchir basal conglomerate, along 105°N fracture	75 × 1–5 Intermittently	<0.010–0.068 (avg = 0.029)	<0.010–0.067 (avg = 0.029)	<0.010–0.020 (avg = 0.014)

eU_3O_8, Measurement based on total gamma counting. If there is no thorium and potassium, then $eU_3O_8 = U_3O_8$.
U_3O_8 (β/γ), Actual value of U_3O_8 by β/γ method.

zones have varying dimensions of 1–75 m length × 0.5–7 m width (Table 2). Mineralization associated with feldspathic sandstone is essentially uraniferous, whereas basal conglomerate is mixed with uranium and thorium (Table 2). Eighteen grab samples of feldspathic sandstone collected from Karwan, Munuva and Alakhdiha have been analysed (<0.010–0.18% eU_3O_8, <0.010–0.16% U_3O_8) and negligible ThO_2. Eight basal conglomerate samples of Ginwar area have been analysed (<0.010–0.068% eU_3O_8, <0.010–0.067% U_3O_8 and <0.010–0.033% ThO_2) (Table 2).

Uranium mineralization associated with feldspathic sandstone occurs along N–S, NW–SE and ESE–WNW fractures. Feldspathic sandstone is fine to medium-grained and consists predominantly of quartz, feldspar, rock fragments, pyrite, limonite, hematite and biotite. Solid state nuclear track detection studies on polished thin sections using cellulose nitrate film (LR115) and etched in alkaline medium at 50°C for 72 h, have registered dense alpha-tracks due to adsorbed uranium on hydrated oxide and secondary uranium minerals. Adsorbed uranium association with martitized magnetite was noticed. Martitization causes oxidation of magnetite to hematite with concomitant reduction of U^{+6} to U^{+4} in solution[7]. Martitized magnetite grains are finally altered to limonite–goethite. The secondary uranium mineral is seen along the periphery of a quartz grain and fracture within the quartz grain. Besides, radioactive goethite and non-metamict zircon have also contributed to low-order radioactivity in the rock. Radioactive limonite indicates secondary mobilization of uranium in the system.

Chemical analysis of uraniferous feldspathic sandstone (n = 8) has revealed 0.013–0.16% U_3O_8 (average = 0.050%), 7.70–8.50% Al_2O_3 (average = 8.20%), 1.40–2.10% Na_2O (average = 1.70%), 2.85–3.10% K_2O (average = 2.95%), 0.26–1.05% FeO (average = 0.67%), 0.54–1.50% Fe_2O_3 (average = 0.94%), 0.08–

0.45% MgO (average = 0.67%), 0.02–0.05% MnO (average = 0.034%), 0.27–0.80% CaO (average = 0.50%), 5–20 ppm Cu of the uranium content. Leachable uranium content is 58.04–87.93%.

The source of uranium in Gondwana sediments appears to be uraniferous crystalline rocks of Surguja comprising quartzo-feldspathic cataclasite, biotite schist, sheared granite–gneiss and pink granite, in which established deposits of uranium, viz. Jajawal and Dumhath are already known in nearby areas. Uranium was most likely remobilized from Surguja crystalline into the sediments and then precipitated in feldspathic sandstone of the Talchir Formation in reducing environment caused due to hematitization of pyrites. Post-Gondwana fractures and faults have facilitated remobilization of uranium from the basement rocks. Uranium mineralization in this area may not occur in isolation and is expected to be widespread in Talchir sandstone. Thus, this discovery has opened a new target area for future exploration for uranium mineralization within the Lower Gondwana sedimentary rocks.

1. Le Roux, J. P. and Toens, P. D., In *Gondwana Six: Stratigraphy, Sedimentology and Palaeontology* (ed. Meckenxie, G. D.), American Geophysics Union, 1987, vol. 419, pp. 139–146.
2. Dahlkamp, F. J., *Uranium Ore Deposits*, Springer-Verlag, Berlin, 1993, p. 460.
3. Virnave, S. N., *Explor. Res. At. Miner.*, 1991, **4**, 49–60.
4. Jain, S. K., Isarailli, I. H., Yadav, O. P., Roy, M. K. and Saxena, V. P., *Gondwana Geol. Mag., Spec. Vol.*, 2007, **10**, 179–184.
5. Jain, S. K., Isarailli, I. H., Banerjee, R. and Roy, M. K., *J. Indian Assoc. Sedimentologists*, 2008, **27**, 15–28.
6. Bhattacharya, H. N., Chakraborty, A. and Bhattacharya, B., *J. Earth Sci.*, 2005, **114**(3), 275–286.
7. Dhanraju, R., Panner Selvam, P. and Virnave, S. N., *Explor. Res At. Miner.*, 1989, **2**, 1–27.

ACKNOWLEDGEMENTS. We thank the Director, Atomic Minerals Directorate for Exploration and Research (AMD), Nagpur for permission to publish this paper. We also thank P. S. Parihar, Additional Director, AMD for encouragement and guidance. Analytical support from the Physics, Chemistry and Petrology Laboratories, AMD is acknowledged.

Received 21 September 2010; revised accepted 9 March 2011

U. P. SHARMA*
R. BIDWAI
S. K. JAIN
M. K. ROY
P. K. SINHA
A. MAJUMDAR

Atomic Minerals Directorate for Exploration and Research,
Department of Atomic Energy,
Civil Line,
Nagpur 440 001, India
**For correspondence.*
e-mail: u_p_sharma@yahoo.com

Tiniest primary producers in the marine environment: an appraisal from the context of waters around India

Phytoplankton (0.2 μm–2 mm) are the major primary producers in the marine environment, thereby forming a basic link in the marine food web. They are categorized into different groups depending on their size range. Cells in the size range of 0.2–2 μm are known as picophytoplankton, which are the smallest known components of the phytoplankton community. Since its discovery in 1988 (ref. 1), vast amount of information has been collected on picophytoplankton in the world oceans[2,3], which shows that these organisms most often dominate the photosynthetic biomass. The picophytoplankton comprises of two cyanobacteria, *Prochlorococcus* and *Synechococcus*, and a range of picoeukaryotes. *Prochlorococcus* is the smallest known photosynthetic organism (0.6–0.8 μm) and the most abundant genus of phytoplankton in open oceans. It contains divinyl derivatives of chlorophylls *a* and *b*. *Synechococcus* (0.8–1.5 μm), which is characterized by an orange fluorescing pigment, phycoerythrin, is found in high abundance in coastal areas, but in low abundance in oligotrophic waters. Picoeukaryotes (1–2 μm), whose major pigment is chlorophyll *a*, include a variety of algal classes such as Prasinophyceae, Pelagophyceae and Bolidophyceae.

Despite the intense interest in the role of picophytoplankton in oceanic planktonic processes, the Northern Indian Ocean (Arabian Sea and Bay of Bengal) is least explored in terms of picophytoplankton distribution. Although there are reports of picophytoplankton from the western Arabian Sea[3,4], there is no detailed information available on the distribution of different picophytoplankton groups from the eastern Arabian Sea. Previous research in these regions was mostly limited to the larger phytoplankton community[5,6] through light microscopy, as a result of which the picophytoplankton went unnoticed due to their small size. With the advent of flow cytometry in biological oceanography, picophytoplankton studies have been made much easier even when compared with epifluorescence microscopy. In view of this, observations on picophytoplankton groups and their abundance are underway in the eastern Arabian Sea and Bay of Bengal (under the Indian Expendable Bathythermographic (XBT) programme) using flow cytometry (BD FACSAria^{TM} II flow cytometer equipped with a blue and red laser emitting at 488 and 633 nm respectively). Some highlights of these observations are presented from the eastern Arabian Sea (coastal: Dona Paula Bay, Goa, 15°27.5′N, 73°48′E; offshore: off Lakshadweep, 10°00′N, 74°30′E; on-board *Sagar Sukti*) and Bay of Bengal (coastal: 21°00′N, 88°11′E; offshore: 16°00′N, 89°00′E). Samples were collected in duplicate at each station, preserved in paraformaldehyde (final concentration 0.2%) and stored in liquid nitrogen until analysis.

Flow cytometry is a technique that allows identification and quantification