Srisailam sub-basin, an uranium province of unconformity-related deposits in Andhra Pradesh – case study of Chitrial uranium exploration, Nalgonda District

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Significant surface radioactive anomalies, with values up to 0.177% eU_3O_8 (n = 9), located during 1992 along the non-conformity contact of basement granitoid with the Srisailam Formation, around Chitrial village, Nalgonda District, Andhra Pradesh, led to the establishment of a sizeable uranium deposit by recent exploration. Thus, intensive subsurface exploration resulted in delineating the persistency of the mineralization over a stretch of 4.4 km (E–W) and 2.7 km (N–S). Along micro-fractures of the granitoid, uranium mineralization occurs as veins of pitchblende and uraninite. Preliminary exploration along the fringes of Srisailam outliers indicated the possibility of establishing substantial uranium reserves within the Srisailam sub-basin, due to similar geological set-up. With increasing thickness of cover sediments towards the centre of the sub-basin, possibility of richer concentration exists in the deeper part of the sub-basin. An attempt has been made to synthesize the exploratory history commencing from locating uranium occurrences up to developing them into a workable economic deposit in Chitrial.

Keywords: Chitrial Plateau, Srisailam outlier, subsurface exploration, uranium-mineralization.

UNCONFORMITY-type uranium deposits are well known for their high grade and large tonnage in the Athabasca basin of Canada and the Pinecreek Geosyncline of Australia[1–5]. In India, consistent efforts are being made to target similar geological environs, where Middle Proterozoic cover rocks overly the Archaean/Lower Proterozoic basement schist, gneiss and granitoid in the Purana basins. The crescent-shaped Cuddapah basin, covering an area of 44,500 km^2 and being the second largest of the Purana basins in Peninsular India, is the most promising in the country for exploring unconformity-related uranium mineralization. The Atomic Minerals Directorate (AMD) for Exploration and Research had initiated reconnaissance radiometric survey in early 1970s in the Cuddapah basin[6–8], and a number of significant uranium occurrences were located along the northwestern margins of the basin at Lambapur and Peddagattu during 1991–92. Chitrial outlier, with geologic set up similar to that of Lambapur and Peddagattu, was located during 1995–96, where radioactive anomalies due to uranium were located in the basement granitoid close to the non-conformity contact with the Middle to Upper Proterozoic cover rocks of the Srisailam Formation. The Chitrial outlier, located along the northeastern fringe of the Srisailam sub-basin, covers an area of 60 km^2, wherein the Srisailam Formation unconformably overlies the basement granitoid. At places, part of the cover rocks has been eroded exposing the non-conformity contact with the granitoid, as in the road-cuttings near Chitrial village. Surface radiometric surveys have indicated the presence of uraniferous occurrences, associated with basement granites, basic dykes and pebbly Srisailam quartzite, close to the non-conformity between the basement rocks and the Srisailam Formation. Samples of the basement granite (n = 65) assayed up to 0.177% eU_3O_8, 0.317% U_3O_8 and <0.005% ThO_2, whereas those of basic dyke (n = 4) assayed up to 0.044% eU_3O_8, 0.065% U_3O_8 and 0.056% ThO_2 (Figure 1 and Table 1). Subsurface uranium exploration in this area was delayed due to logistic constraints. The exploratory non-coring drilling, that commenced in November 2005, established the subsurface continuity of uranium mineralization along the margins of the Chitrial Plateau.

The area exposes the Lower Proterozoic grey, coarse-grained, biotite granite (epidotized and pyritized), traversed by dolerite dykes, quartz and pegmatite veins. The overlying Srisailam Formation comprises basal pebbly horizon, conglomerate, green gritty quartzite, intercalation of dark grey shale-quartzite and dirty white, medium-to-coarse-grained feldspathic quartzite[9]. The non-conformity contact between the basement and the Srisailam Formation is exposed in the road section leading to Chitrial village, under a thin layer of cover rocks of 2–3 m. The basement granite is essentially composed of quartz, orthoclase, microcline, plagioclase and biotite, with accessory zircon, apatite and allanite. Anatase, limonite, goethite and pyrite are the ore minerals noticed in grab samples. It is A/CNK peraluminous (A/C + N + K = 1.700), enriched in K_2O (av. 5.63%; n = 12), SiO_2 (av. 71.45%) and Al_2O_3 (av. 15.15%), and depleted in CaO (av. 0.22%). The entire Chitrial Plateau is traversed by doleritic dykes. The dolerite dykes are fine-grained, melanocratic, greyish-black in colour and altered with an assemblage consisting of sericite, calcite, chlorite and uralite. Ore minerals, viz. anatase, leucoxene and goethite are present in the basic rocks.

The overlying Srisailam Formation is made up of subfeldspathic quartzite, often ferruginous and intercalated with shale. The quartzite displays primary sedimentary structures, viz. bedding, laminations, cross-stratification, ripple marks, etc. Pyrite, hematite and goethite are its ore

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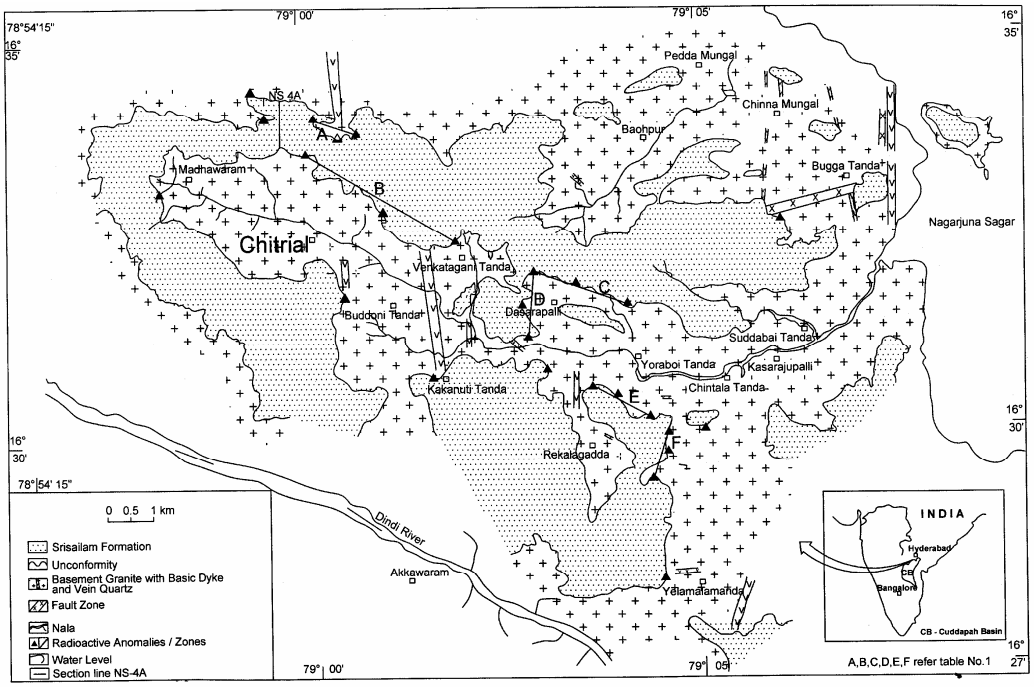

Figure 1. Geological map of Chitrial Plateau, Nalgonda District, Andhra Pradesh showing cluster of uranium anomalies.

Table 1. Radiometric analysis of grab samples of Chitrial Plateau, Nalgonda District, Andhra Pradesh

Arm	Slope	Locality	Dimensions (length × thickness)	Rock type	*n*	Average radiometric assay		
						$\%eU_3O_8$	$\%U_3O_8$	$\%ThO_2$
Northern	Northern	North of Chitrial (A)	1.5 km × 1–1.5 m	Granite	9	0.177	0.317	0.005
	Southern	North of Chitrial (B)	8 km × 1–2 m	Granite	30	0.144	0.208	0.005
	Southern	Dasarapalli (C) and (D)	4 km × 1 m	Granite	12	0.063	0.101	0.005
			3 km × 1 m	Granite				
Southern	Northern	East of Kakanuti Tanda (E)	1.3 km × 2 m	Granite	11	0.035	0.068	0.005
		East of Rekalgadda (F)	1 km × 3 m	Granite	3	0.036	0.034	0.005
	Southern	ENE of Venkatagani Tanda and NE of Dasarapalli		Basic dyke	4	0.044	0.065	0.056
Total					69			

minerals. There are three prominent fracture sets present in the area, trending in the N–S, NNE–SSW and NW–SE directions.

Exploratory drilling was initiated in the Chitrial Plateau in November 2005, with the first phase of drilling covering an area of 4.4 km (E–W) and 2.7 km (N–S), through 129 non-coring boreholes, aggregating to 6871.70 m of drilling. The objective of the first-phase drilling was to delineate the limits of uranium mineralization in an initial area of 10 km^2. Boreholes were planned on a 400 × 400 m and 200 × 200 m diamond grid pattern so as to sample the entire 10 km^2 area in a rapid mode for a quicker appraisal of the area. As the first phase of drilling indicated a positive output, combination of core and non-core drilling was started in May 2007. So far 300 boreholes have been completed, with a clear-cut demarcation of limits of uranium mineralization necessary for estimation of the ore reserves.

A preliminary statistical analysis of the 129 boreholes drilled at Chitrial indicates that 73 intercepted uranium mineralization at >0.020% eU_3O_8 cut-off grade × 1.20 m thickness and 31 intercepted mineralization between 0.010 and 0.020% eU_3O_8 cut-off grade, while 13 were going barren and 12 were abandoned. Continuation of uranium mineralization was established over a strike length of 1.2 km and a plan width of 0.6 km in the western sector and 2 km × 1 km in the eastern sector, with a gap of 400 m between the two. Mineralization in the form of a flat, tabular, concordant body, is hosted by the Lower Proterozoic granite, below the cover rocks of the Middle Proterozoic Srisailam Formation, along their unconformity contact, as intercepted in the CTR boreholes drilled from

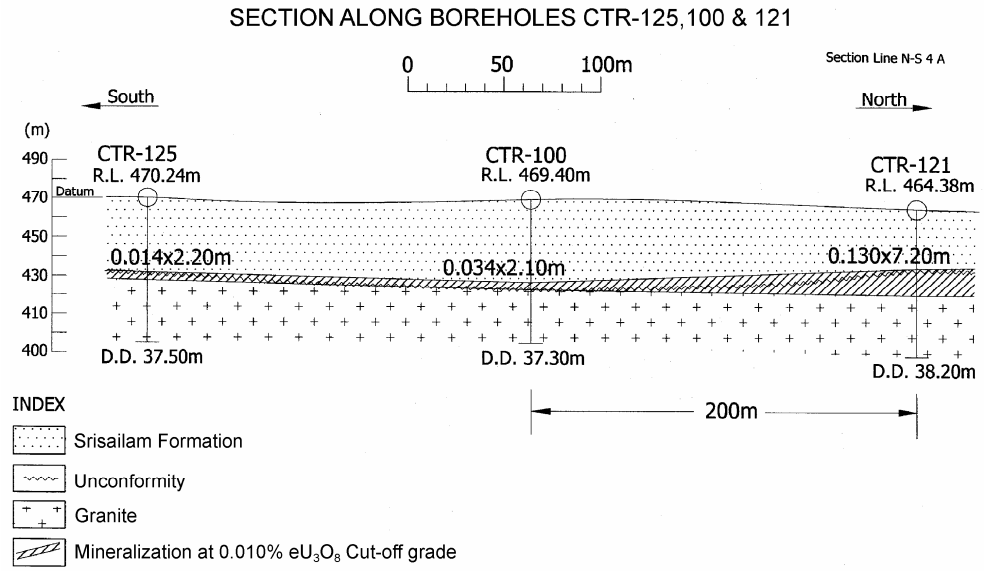

Figure 2. North-south section of boreholes drilled in Chitrial Plateau.

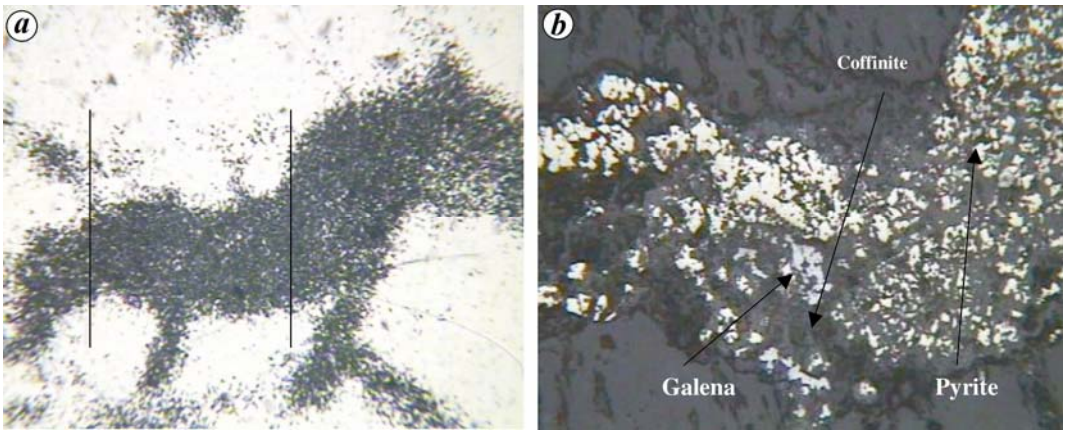

Figure 3. ***a***, Alpha tracks of pitchblende vein within granite CTR/230. Area bounded by two lines are magnified and shown in reflected light as (***b***). ***b***, Vein of pitchblende completely coffinitized in granite, and sulphides represented by galena and pyrite. RL, 20×, 1N; scale: 1 cm = 69 μm.

the Srisailam Formation. The depth of the ore body varies from 8 to 30 m in the western sector and 9 to 74 m in the eastern sector. Uranium mineralization of 0.130% eU_3O_8 × 7.20 m intercepted in borehole no. CTR/121 in the western sector is the richest radioactive band, intercepted in the entire Chitrial block (Figure 2). Thickness of ore body varies from 1.0 to 7.20 m, with an average value of 2.45 m.

Ore body follows non-conformity contact. Uranium phases identified in Chitrial block include (a) uraninite as inclusions in feldspar, (b) secondary uranium minerals along thin hairline micro-fractures, (c) metamict allanite and zircon, and (d) veins of pitchblende. Veins of pitchblende within granite and its corresponding alpha tracks intercepted in the borehole core of CTR-230 are shown in Figure 3. Pitchblende is highly coffinitized and associated with galena and pyrite (Figure 3 *b*). Uraninite occurs as inclusions in biotite and feldspar appears to be of an earlier generation, high-temperature, syn-magmatic type, whereas pitchblende of later generation, lower temperature, hydrothermal-type occurs as fracture fillings and veins show epigenetic nature. Uranophane is present as secondary uranium minerals close to the fracture zone in the basement granitoid. Large-scale alteration, viz. illitization of feldspar and chloritization of biotite is noted in the ore-zone granitoids. Granite analysed showed higher content of Cr (av. 117 ppm), Co (av. 63 ppm), and Ni (av. 197 ppm). Further, Chitrial granites are considerably rich in chlorite (alteration of biotite), up to 17.50%, which aids in fixing the mineralization. Large-scale intergranular fracturing, recrystallization of quartz, and granulation of quartz and feldspar might have further necessitated forma-

tion of a richer concentration close to the unconformity contact, aided by the presence of suitable reductants in the form of grey to black coloured, thinly laminated shale and pyrite. Hydrothermal signatures in the form of bleeding pyrite in the granite are also predominantly seen.

Subsurface correlation sections, prepared to understand configuration of ore body, reveal that the mineralization of Chitrial persists in grade and thickness along the non-conformity contact between basement biotite granitoid and the Srisailam Formation and continues over a strike length of 2 km. Based on the method of triangles, reserves of approximately 6000 t were estimated, with an average grade of 0.068% eU_3O_8 in the inferred category by the first series of non-coring boreholes in a grid pattern of 200 × 200 m for 4 km in the E–W direction and nearly 2 km in the N–S direction. Dip of ore body varies from 4 to 5° due SE. Accumulation contour plan of the ore body depicts a NW–SE trend, which is also the major fracture trend of this area. This feature supports the role of fractures in controlling U-mineralization, besides non-conformity contact with basement granitoid. Detailed exploration is currently underway to establish the uranium potential of the area. So far only the fringe areas with a thin cover of Srisailam sub-basin have been covered by exploration. The central part with a thick cover still remains to be explored and the possibility of striking richer mineralization in the near future is plausible.

1. Jefferson, C., Gandhi, S., Ramakers, P., Delaney, G., Thomas, D., Cutts, C. and Olson, R., Unconformity-associated uranium deposits: 2005 Convention CD-ROM. Prospectors and Developers Association of Canada, Toronto, 2005.
2. Wall, V. J., Johnston, J. D. and Koul, S. L., The plumbing systems of unconformity-related uranium deposits. International Conference on Concentration Mechanisms in Geological Environments, CREGU, Nancy, 1985, pp. 225–230.
3. Cuney, M L., World-class unconformity-related uranium deposits: key factors for their genesis. In *Mineral Deposit Research: Meeting the Global Challenge* (eds Jingwen, M. and Bierlein, F. P.), Proceedings of the Eighth Biennial SGA Meeting, Beijing, 18–21 August 2005.
4. Ferguson, J., Chappell, B. W. and Goleby, A. B., Granitoids in the Pine Creek Geosyncline. In *Uranium in the Pine Creek Geosyncline* (eds Ferguson, J. and Goleby, A. B.), IAEA, Vienna, 1980, pp. 73–90.
5. Hoeve, J., Sibbald, T. I. I., Ramaekers, P. and Lewry, J. F., Athabasca Basin unconformity-type uranium deposits: a special class of sandstone type deposits. In *Uranium in the Pine Creek Geosyncline*, IAEA, Vienna, 1980, pp. 575–594.
6. Sinha, R. M., Parthasarathy, T. N. and Dwivedy, K. K., The possibility of identifying low cost, medium grade uranium deposits close to the Proterozoic unconformity in Cuddapah basin, Andhra Pradesh, India. In Paper presented at the IAEA Technical Committee Meeting, 'Innovation in Uranium Exploration, Mining and Processing Techniques and New Exploration Target Areas', Vienna, December 1994.
7. Jeyagopal, A. V., Prakhar Kumar and Sinha, R. M., Uranium mineralization in the Palnad sub-basin, Cuddapah Basin, Andhra Pradesh, India. *Curr. Sci.*, 1996, **71**, 957–959.
8. Sinha, R. M., Shrivastava, V. K., Sarma, G. V. G. and Parthasarathy, T. N., Geological favourability for unconformity related uranium deposits in northern parts of the Cuddapah Basin: evidences from Lambapur uranium occurrence, Andhra Pradesh, India. *Exp. Res. At. Miner.*, 1995, **8**, 111–126.
9. Nagaraja Rao, B. K., Rajurkar, S. T., Ramalingaswamy, G. and Ravindra Babu, B., Stratigraphy structure and evolution of the Cuddapah Basin. *Geol. Soc. India, Mem.*, 1987, **6**, 33–86.

ACKNOWLEDGEMENTS. We thank the officers and staff of Physics, Chemistry, XRF and Petrology laboratories, AMD for providing the analytical support.

Received 25 April 2008; revised accepted 18 December 2008