Uranium mineralization in the sandstones of Dharamsala, Tileli area, Mandi district, Himachal Pradesh, India

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We report here the discovery of sandstone-hosted uranium mineralization in the basal part of Upper Dharamsala Formation in Mandi district, Himachal Pradesh. Stratigraphically, the Tertiary sedimentary rocks of Dharamsala Group (Upper Eocene to Lower Miocene; 1400 to 1900 m thick in Tileli area and locally up to 3950 m thick) are bounded by the Main Boundary Thrust (MBT) on the north-east and Palampur Thrust on the south-west, with several other criss-cross thrusts. The beds dip 30°–55° north-east.

Uranium mineralization was noted at Tileli (eU_3O_8, 0.086%), and was explored by shielded probe logging of rocks exposed in five trenches. The trench face samples assayed 0.01–0.27% eU_3O_8, and 0.011– 0.076% U_3O_8 (beta/gamma) with negligible ThO_2. The radioactive zone is 540 m long and 5–10 m thick. Radioactivity is due to uraninite and uranophane disseminated in radioactive pockets which are enclosed in hydrated iron oxide, at places admixed with clay.

In addition to Tileli, other significant uranium manifestations are Rohin Khad (50 m × 10–15 m); eU_3O_8, 0.069%), Garlwar (70 m × 5–8 m; eU_3O_8, 0.063%), Chah Ka Dora (80 m × 10–15 m; eU_3O_8, 0.036%), Kalthar (50 m × 5–8 m), Mangwana (5 m × 2 m; eU_3O_8, 0.88%) and Manjkhetar (eU_3O_8 values from grab samples). This study opens up a new environment in Dharamsala basin to locate possible new uranium prospects.

RECENT investigations in the Upper Eocene–Lower Miocene Dharamsala sequence of rocks in the north-western foot-hill of the Himalaya have led to the discovery of sandstone-hosted uranium mineralization extending for about 540 m with 5–10 m width at Tileli, 52 km south-west of Mandi in Himachal Pradesh. Grab samples assayed up to 0.28% eU_3O_8, 0.31% U_3O_8 (beta/gamma) and < 0.005% ThO_2, with majority of the samples showing disequilibrium in favour of parent uranium. Radioactive minerals identified are uraninite and uranophane in association with organic matter, hydrated iron oxide, at places admixed with clay.

Exploration by the AMD to locate sandstone-hosted uranium mineralization in Dharamsala commenced during the early 1990s with the Group is fulfilling most of the favourability criteria like fluvio-deltaic environment, proximity of a uranium provenance, and presence of reductants like organic matter, framboidal pyrite and clays. This resulted in locating many sandstone-hosted uranium anomalies at Tileli, Chah Ka Dora, Garlwar, Kalthar, Mangwana, Manjkhetar and Rohin Khad in Mandi and Bilaspur districts of Himachal Pradesh. In the present report, the discovery of uranium mineralization at Tileli has been dealt with.

Tileli (lat. 31°29′10″N; long. 76°48′20′E; toposheet 53 A/15) is located in the Mandi district of Himachal Pradesh (Figure 1 *b*). The Dharamsala Group at Tileli is bounded in the north-east by the MBT and in the south-west by Palampur Thrust and criss-crossed by other prominent thrusts like Galma, Joginder Nagar, Rewalsar, Bhamla[1], etc. (Figure 1 *a*). It comprises Tertiary sedimentary rocks with a few occurrences of unclassified granite[2]. Stratigraphically, the Dharamsala Group comprises Upper Eocene to Lower Miocene litho-units and is underlain by sediments of the Subathu (Palaeocene (?) to Eocene age) and overlain by Siwalik sediments of Middle Miocene to Lower Pleistocene age (Table 1). Lithologically, the Dharamsala Group is subdivided into Lower and Upper Dharamsala Formations. The Lower Dharamsala Formation (LDF) is predominantly argillaceous consisting of red, purple shales with minor grey shales and subordinate amount of grey–brown sandstones. The sandstones of LDF is more micaceous whereas the variegated shale contains more criss-cross closely spaced calcite veins. The Upper Dharamsala Formation (UDF) is arenaceous composed of hard, compact, greenish-grey sandstones interbedded with grey shales with minor red, brown splintary shale. The latter is confined to the lower part.

Table 1. Generalized stratigraphic succession of Dharamsalas

Siwalik Group–Middle Miocene to Lower Pleistocene	
Dharamsala Group–Upper Eocene to Lower Miocene	Upper Dharamsala – greenish-grey sandstones and greenish-grey maroon shales and minor red–brown shales
	Lower Dharamsala – red and brown shales with minor grey shales and grey–brown sandstones
	Igneous rocks – unclassified
Subathu Group – Palaeocene(?) to Eocene	

Table 2. Radiometric assay values (averages in %) of mineralized sandstones from Tileli and other localities, Tileli area, Mandi district, Himachal Pradesh

Locality	Number of samples	eU_3O_8	U_3O_8 (beta/gamma)	ThO_2
	Grab			
Tileli	40	0.086	0.060	< 0.005
Chah Ka Dora	10	0.036	0.042	–
Garlwar	02	0.063	0.107	< 0.005
Mangwana	01	0.880	1.500	–
Rohin Khad	03	0.069	0.114	< 0.005

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The sandstones of UDF are characterized by the presence of leaf impressions, stem and trunk (fossil log) which indicates a fluviatile environment. The boundary between the LDF and UDF is marked by the appearance of a thick and laterally persistent sandstone band above which the sequence becomes more arenaceous compared to Lower Dharamsala[3]. The estimated thickness of Dharamsala Group of rocks at Tileli ranges from less than 1400 m to

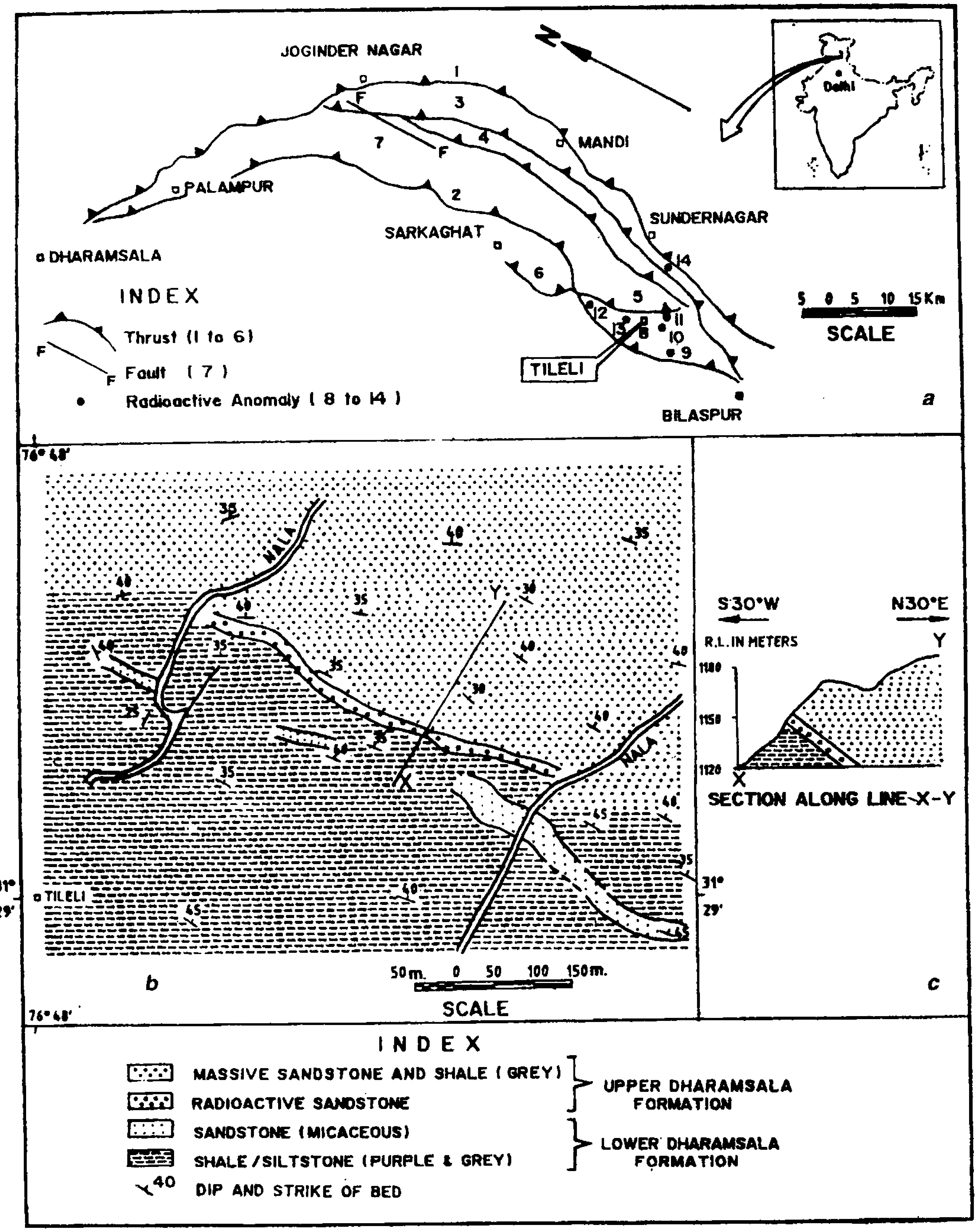

Figure 1. *a*, Location map of Tileli, 1. Main Boundary Thrust, 2. Palampur Thrust, 3. Galma Thrust, 4. Jogindernagar Thrust, 5. Rewalsar Thrust, 6. Bhamla Thrust, 7. Fault, 8. Study area (Tileli anomaly), 9. Rohin Khad anomaly, 10. Garlwar anomaly, 11. Chah-Ka-Dora anomaly, 12. Kalthar anomaly, 13. Manjkhetar anomaly, 14. Mangwana anomaly; *b*, Geological map of the Tileli area; *c*, Section along line X–Y.

1900 m. In some sections, however, the Group is up to 3950 m thick. The Dharamsala beds have dips of 30° to 55° towards north-east.

Reconnaissance radiometric surveys around Tileli village during 1996–97 led to the discovery of radioactive zones at about 0.75 km east-north-east of Tileli village (Figure 1 *b*). A radioactive zone of 540 m was traced with its width varying from 5 to 10 m in the sandstones of the basal part of the UDF, near the contact with the LDF. In general, the radioactive zones record radioactivity of 0.03 mR/h to 0.1 mR/h, with several patches showing higher orders of radioactivity up to 0.5 mR/h. Other significant radioactive anomalies were also picked up at Rohin Khad (50 m × 10–15 m) and Garlwar (70 m × 5–8 m). Grab samples from these localities assayed 0.012 to 0.14% eU_3O_8; eU_3O_8 expresses gross radioactivity in terms of equivalent uranium (eU), defined as 'the amount of uranium in equilibrium with its daughter elements, required to give the same counting rate as the sample in a particular type of instrument' and 0.014 to 0.27% U_3O_8 (beta/gamma) (Table 2). During 1997–98, additional significant radioactive anomalies were located at Chah Ka Dora (80 m × 10–25 m), Kalthar (50 m × 3–8 m), Manjkhetar (100 m × 1–2 m) and Mangwana (5 m × 2 m). Grab samples from these localities assayed 0.011 to 0.88% eU_3O_8 and 0.010 to 1.5% U_3O_8 (beta/gamma) (Table 2).

Preliminary petrographic and mineralogical studies indicate that the host rock for uranium mineralization is moderately sorted, subfeldspathic arenite. It shows grain-packed texture and mainly comprises clasts of subrounded quartz (80–85%), rock fragments of phyllite, quartzite, gneisses and negligible feldspar set in an argillaceous matrix (6–7%). Biotite, muscovite, chlorite, rounded zircon, green tourmaline, hematite and ilmenite occur as minor minerals. The organic matter occurs as pore-fillings and veins, and contains tiny framboidal granules of pyrite suggestive of its biogenic origin. Radioactivity is due to uraninite and uranophane, in association with organic matter where radioactive minerals occur as dissemination in the radioactive pockets. These pockets are enclosed within the light-brown coloured thin rim of hydrated iron oxide, at places admixed with clay. These pockets are poorly to moderately sorted, and mainly consist of subrounded to subangular quartz, rock fragments of phyllite and quartzite with negligible plagioclase. Chalcopyrite is present in the rock fragments of phyllite.

Detailed geological and structural work commenced to prove the qualitative and quantitative surface manifestations, and a total of five trenches and four faces were prepared for Shielded Probe (SP) logging. The results of the SP logging have indicated persistency of uranium mineralization over the strike length of 540 m. The SP logging data at cut-off grade of 0.02% eU_3O_8 have indicated average grade 0.039% eU_3O_8 and average exposed width 2.64 m. The channel samples drawn from the above trenches and faces have analysed 0.01–0.27% eU_3O_8, and 0.011–0.076% U_3O_8 (beta/gamma) with negligible ThO_2.

In view of the above data, favourable geological setting, presence of high concentration of uranium in association with organic matter, hydrated iron oxide, at places admixed with clay, the discovery of uranium mineralization in sandstones of Dharamsalas at Tileli has opened up a new environment for survey and exploration of uranium in the Dharamsala basin.

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Structure and tectonics of the Indian peninsular shield – Evidences from seismic velocities

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The Indian shield is an assemblage of cratons and mobile belts. Significant lateral variations in the crustal velocity structure, especially the presence and absence of crustal low/high velocity layers are found to provide an useful input in understanding the structure and evolution of various important tectonic units present in the Indian shield. The subsurface velocity heterogeneities have been shown to provide clues to estimate the stress generation and in understanding to some extent, the seismicity of intraplate regions. Significance and the geophysical aspects of low velocity layers are discussed. Other geophysical anomalies such as gravity, heat flow and seismicity are also discussed with reference to craton and mobile belt.

SHIELD is made up of a cratonic nucleus with a mobile belt at its periphery. A craton is a stable portion of a shield area with low-grade granite–greenstone terrain, which is unaffected by major tectono-thermal events since the end of Precambrian. On the other hand, the mobile

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