Table 1. Soil organic carbon (SOC) stock (up to 1 m soil depth) of different tropical landuses

Ecosystem	Region	SOC (Mg ha^{-1})	Reference
Dipterocarpus forests	North East India	141.13	11
Rubber *(Hevea brasiliensis)* plantations	China	154.9	12
Cacao + *Gliricidia* (*Gliricidia sepium*)-based agroforestry	Indonesia	155	13
Cacao *(Cocao cabruca)*	Brazil	192.6	14
Natural forests	Kerala	176.6	15
Rice (*Oryza sativa*) – paddy		55.6	
Coconut (*Cocos nucifera*)		91.7	
Small home gardens		119.3	
Natural forests	Brazil	137.3	14
Herbs and grass-dominated natural forests	Bangladesh	168.15	16
Agricultural lands	Thailand	136.34	17
Wetlands	North East India	220.25	Present study

revolution due to human activities such as conversion of wetlands to farmlands, forestry and urban areas[18]. Therefore, SOC stored in wetlands is not well protected; rather, their mismanagement has turned such large SOC sinks into a net source[5] and further exacerbated ecosystem dis-services. To halt further degradation of such SOC-rich systems, preservation and restoration of wetlands is important for enhancing terrestrial carbon sinks. Moreover, wetland agroforestry can be promoted that can alleviate poverty by making substantial contribution towards local economy[19]. Furthermore, drainage and deforestation that result from farmland expansions must be prohibited. Restoration of wetlands can be promoted by providing incentives to the land managers through payment of ecosystem services.

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A new occurrence of tapiolite from Kuberpur pegmatite, Surajpur district, Chhattisgarh, India

Survey and exploration for atomic minerals have been carried out in the past couple of decades by the Atomic Minerals Directorate for Exploration and Research (AMD) in parts of migmatitic terrain of erstwhile Sarguja district, Chhattisgarh and Sonbhadra district, Uttar Pradesh (UP), India. This has resulted in identification of several atomic mineral occurrences. The geological terrain of Sarguja has been studied earlier. Discovery of atomic minerals commenced with the identification of beryl and columbite–tantalite in pegmatites in the early 1960s (Tatachar and Sheshadri, unpublished; ref. 1). Subsequently, detailed work in the area resulted in the identification of many more such beryl and columbite–tantalite-bearing pegmatites (Khandelwal and Tiwary, unpublished; ref. 2). Detailed study in areas located further north, in parts of Sonbhadra district, UP, also led to the discovery of rare metals and rare earth mineralization in the form of columbite tantalite, eschynite, samarskite, fergusonite, uranothorite and thorite along with rutile and zircon in pegmatitic injections at Jaurahi[3]. Recently, a survey carried out for rare metals and rare earths helped locate a cluster of zoned granite–pegmatite around Kuberpur (23°52′27″N, 82°41′39″E), Surajpur district, Chhattisgarh (Figures 1 and 2).

Presence of discrete mineral phase of tapiolite (oxide of Ta and Nb) in the granite–pegmatite at Kuberpur is reported here. Topographically, the tapiolite-bearing pegmatite occurrence of Kuberpur is located along the eastern bank of Khiro Nadi, a tributary of Rehar river. The Kuberpur pegmatite occupies the western bank of Khiro Nadi close to Madhya Pradesh border. The general trend of rock formation is E–W to ENE–WSW (corresponding to Satpura orogeny lineament) with sub-vertical dips (70–80°) towards north.

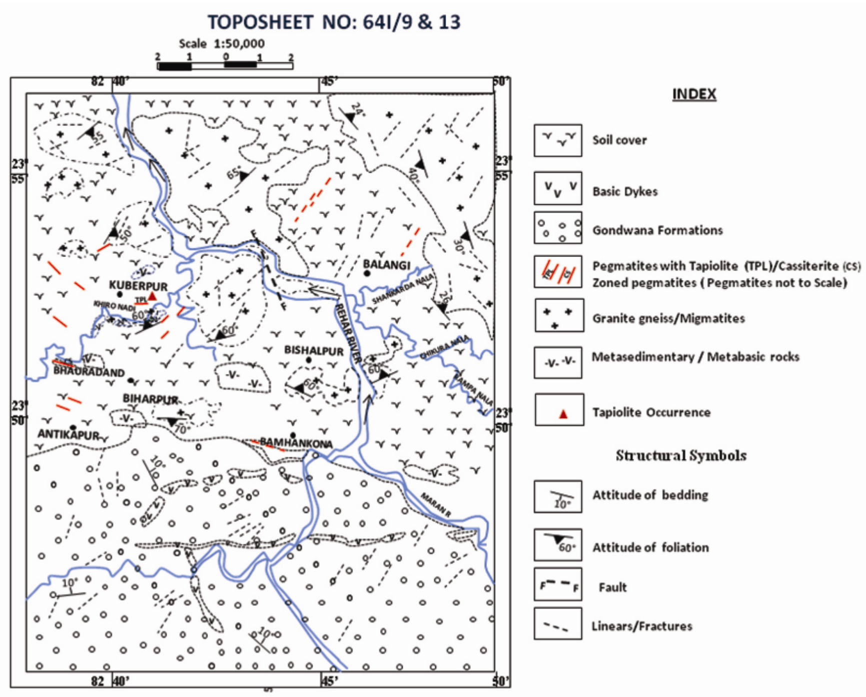

Figure 1. Geological map of Kuberpur area, Surajpur district, Chhattisgarh, India.

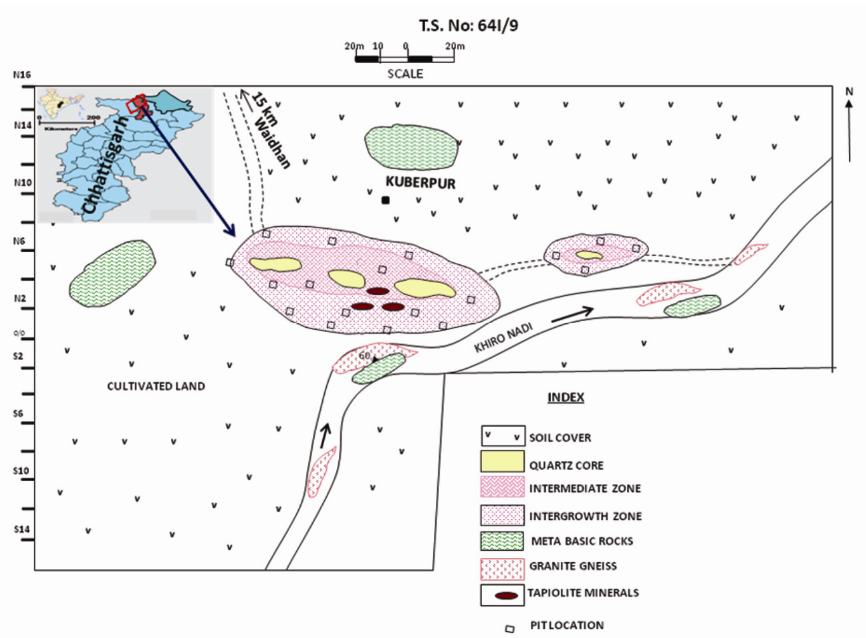

Figure 2. Geological map of Kuberpur pegmatite, Surajpur district, Chhattisgarh.

The Kuberpur area forms the western extension of Chhotanagpur Granite Gneiss Complex (CGGC). It consists of narrow inliers of Precambrian rocks exposed within the Gondwana sediments. The Precambrian is represented by metasedimentary rocks, migmatites, porphyritic granite gneisses, pegmatites, quartz veins and dolerite dykes. The metasedimentary rocks are represented mainly by muscovite–biotite schist, chlorite–biotite schist, amphibolites and quartzites, whereas the metabasic rocks consist of amphibolites/hornblende schists. Pegmatites occur as swarms in schists that are migmatized. Though the general trend of rock formation is E–W to ENE–WSW with sub-vertical dips (70–80°) towards north, frequent reversals in dip are observed due to polyphase deformations[4,5]. It is reported that the metasediments and associated migmatites were formed during Chhotanagpur orogeny (1500–1600 Ma), whereas younger granites and pegmatites along with some basic rocks and sills were emplaced during syn- to post-Satpura orogeny (950–900 Ma)[4,5]. The contacts between crystalline complex and the Gondwana Supergroup are faulted, fractured and sheared, which follow parallel to sub-parallel disposition to the prominent ENE–WSW-trending tectonic zone. Post-Gondwana igneous activity is marked by the presence of dolerite dykes within the Gondwana rocks, which are also affected by later faults[4].

Kuberpur pegmatite is asymmetrically zoned and differentiated with a prominent quartz core. This core is followed by perthitic intermediate zone, which in turn is followed by quartz–feldspar intergrowth zone. It extends over 350 m in length and 150 m in width trending N80°W–S80°E to E–W, emplaced along the contact of metabasic rocks (amphibolites) and granite gneisses.

The tantalum mineral ‘tapiolite’ has a tetragonal symmetry and derives its

Table 1. Results of major elemental analyses of tapiolite from Kuberpur, Surajpur district, Chhattisgarh, India and comparison with other Indian and world occurrences

Oxides/ elements	KBR/ 14-15/1(a) tapiolite	KBR/ 14-15/2 tapiolite	Tapiolite* from Arehalli, Karnataka, India	Tapiolite** from Sukkula, Tammela, Finland	Tapiolite** from Rockford, Albama, USA	Tapiolite** from Greenbushes, Australia	Tapiolite** from Rio Grande do Norte, Brazil
TiO_2	0.82	0.83	3.80	0.11	1.31	0.54	1.02
Fe_2O_3	14.07	13.97	13.30	13.65	12.05	11.51	12.67
MnO	1.32	1.37	0.67	0.67	1.42	1.81	1.16
Nb_2O_5	6.93	6.84	3.80	8.96	4.06	2.59	6.14
Ta_2O_5	73.81	73.54	79.80	73.61	79.91	83.90	79.61
SnO_2	0.68	0.64	0.42	1.25	0.91	0.36	0.64
ThO_2	<0.01	<0.01	–	–	–	–	<0.01
U	0.02	0.02	–	–	–	–	0.02
Total	97.66	97.22	101.79	98.25	99.66	100.71	101.27

*Ref. 8; **ref. 7.

Table 2. Trace element contents in muscovite and feldspar from Kuberpur, Surajpur district, Chhattisgarh

Trace elements	KBR/14-15/3 feldspar	KBR/14-15/4 muscovite	KBR/14-15/8 muscovite
Rb	1772	3342	2098
Sr	<10	10	<10
Y	<10	15	<10
Zr	10	17	21
Nb	37	375	622
Ba	15	<10	47
Ce	<10	<10	12
Pb	129	12	11

The feldspar sample analysis shows high K_2O (12.63%).
XRF data analysed by Chanchal Sarbajna, AMD, Hyderabad.

name from 'Tapio', the mythological forest God in Finland, where it was first discovered[6,7]. Tapiolite from Kuberpur is black, massive and either blocky or finely fragmented. It shows sub-metallic lustre and uneven fracture, and a hardness of 6.5 on Moh's scale. It occurs in association with other pegmatitic minerals. Majority of tapiolite pieces are found to be dispersed in deluvial/eluvial pegmatite gravel away from the quartz core. Many of the test pits put in intermediate zone of the pegmatite have shown the presence of tapiolite. This zone is represented mainly by feldspar. The intermediate zone is sandwiched between the quartz core and intergrowth zone, consisting of quartz and feldspar. The grade of 100–450 g/te of the mineral by weight has been recorded in preliminary test pitting and panning over a small area of 30 m × 30 m at Kuberpur. Individual tapiolite pieces are found to vary in size from <1 mm to 6 cm across (Figure 3). One of the panned mineral concentrate sample is has been chemically analysed and contains 69.10% Ta_2O_5, 11.4% Nb_2O_5, 12.9% FeO and very less MnO (1.29%). In addition, 0.6% TiO_2, 0.75% SnO_2 and >0.25% WO_3 have also been recorded in the sample.

One more pegmatite occurrence is recorded at Bhauradand (23°51′19.1″N, 82°38′58.9″E) in the nearby locality of Kuberpur. This pegmatite has shown minor cassiterite mineralization and a panned concentrate sample from gravels shows 75.60% SnO_2, 6.80% Ta_2O_5 and 5.10% Nb_2O_5 (chemical).

Both niobium and tantalum occur together in nature due to their geochemical similarity, i.e. similar ionic radii and valency. Tables 1 and 2 provide results of the major and trace element analyses of the two handpicked tapiolite mineral pieces and selected trace element analyses of two samples of muscovite and one sample of K-feldspar from the pegmatite of Kuberpur, Surajpur district.

The WDXRFS-based analyses of two tapiolite samples show very high Ta_2O_5 (73.81% and 73.54%) and Fe_2O_3 (t) [14.07% and 13.97%], low Nb_2O_5 (6.93% and 6.84%) and MnO (1.32% and 1.37%), minor TiO_2 (0.82% and 0.83%) and very low SnO_2 (0.68% and 0.64%). Both the samples contain 0.02% U_3O_8 and <0.01% ThO_2. The analyses indicate Ta and Fe rich nature of the minerals, which chemically resemble tapiolite [(Fe, Mn) (Ta, Nb, Ti)$_2$O$_6$]. This has been confirmed by XRD studies/lattice parameters. They are comparable with tapiolite mineral found in Tammela, Finland[7], Rockford, Albama, USA[7] and Arehalli, Karnataka, India[8]. Compared to the tapiolite of these localities, Kuberpur tapiolite is rich in Ta_2O_5 but has Ta_2O_5 content less than tapiolite of Greenbushes, Australia, Rockford, Albama, USA[7] and Arehalli, Karnataka[8]. Kuberpur tapiolite has Ta_2O_5/Nb_2O_5 ratio of 10.65 and 10.74, whereas tapiolite from Sukkula, Finland has a ratio of 8.22; Greenbushes, Australia 32.39; Rockford; USA 19.68; Rio Grande, Brazil 13.01 and Arehalli, Karnataka 21. This could be due to less content of Nb_2O_5 in the

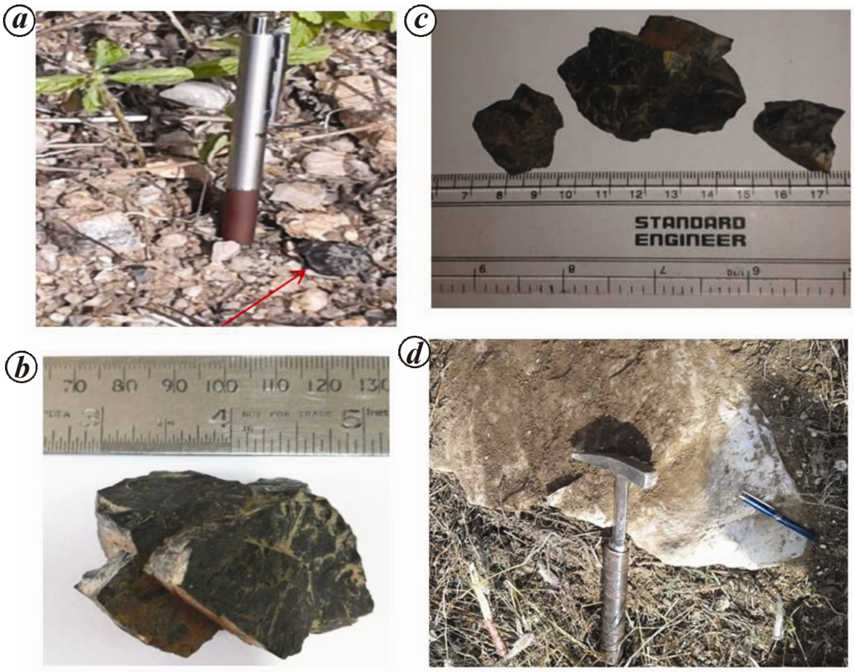

Figure 3. ***a***, Tapiolite in gravels of Kuberpur pegmatite. ***b***, Tapiolite from Kuberpur pegmatite. ***c***, Tapiolite pieces from Kuberpur pegmatite. ***d***, Quartz core in Kuberpur pegmatite.

mineral or possible replacement of Nb by other high field strength elements. One feldspar (Table 2) sample analysed from the pegmatite shows very high K_2O (12.63%), SiO_2 (65.02%) and Al_2O_3 (18.68%), very low Na_2O (1.73%) and CaO (0.02%) and high Rb (1772 ppm), indicating presence of K-feldspar and lack of albitization. The muscovite samples show 375 and 622 ppm Nb, indicating indirectly the possible Nb–Ta mineralization as Nb content is always found quite high in micas, where the pegmatites host mineralization of Nb and Ta minerals.

In view of widespread occurrences of pegmatites in north Sarguja crystallines, further survey and exploration for rare metals and rare earth mineralization may prove rewarding.

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