Figure 4. Four inch diameter multi-crystalline Si ingot from rice-husk (adapted from ref. 10).

Siemens process. Alumino-thermic reduction should require even less energy due to the considerably lower temperature of reduction. Further reduction of Al content is required by slagging or directional solidification.

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Uranium mineralization in Palaeoproterozoic Khetabari Formation, Bomdila Group, Sie-Rimi area, West Siang district, Arunachal Pradesh

The Palaeoproterozoic low-grade metasedimentary rocks of Bomdila Group, Arunachal Pradesh, occurring as a NNE to NE trending belt in the easternmost part of the Lesser Himalaya have been recognized as favourable hosts for uranium mineralization. Its basal subdivision, the Khetabari Formation having ferruginous, calcareous quartzitic metasediments, graphitic/carbonaceous phyllite, minor carbonates, chert and para-amphibolite and garnetiferous psammopelites is bounded by the Permocarboniferous Gondwana equivalent Miri quartzite in the east and with the 1.9-Ga-old intrusive Bomdila/Ziro Gneisses in the west. The rocks of the Khetabari Formation show multiple episodes of deformation. The F_1 folds usually identifiable in the psammitic rocks of the Khetabari Formation are of isoclinal geometry. The most pervasive planar fabric S_1 is developed parallel to the axial plane of the F_1 folds and in most places parallel to the S_0 plane (original bedding plane), except near the hinges. The F_2 folds dipping at moderate to steep angles towards SE developed during the subsequent deformation are superimposed over F_1. Co-axial refolding of the F_1 folds producing crenulation cleavage (S_2) is found generally in the limbs of the isoclinal folds within quartzo-feldspathic schists[1]. Effect of ductile shearing within the psammo-pelites of the Khetabari Formation is evident by the presence of asymmetric quartz porphyroclasts having long tail, sigmoidal-shaped quartz laminae in the schistose portion, pinch and swell of quartz grains, etc.

Exploration efforts over three decades have resulted in locating about 200 uranium occurrences in a variety of rocks mainly of Palaeoproterozoic age. Conspicuously, uranium mineralization in all these lithounits is invariably associated with sulphides. Sericitization, chloritization, hematitization and silicification are

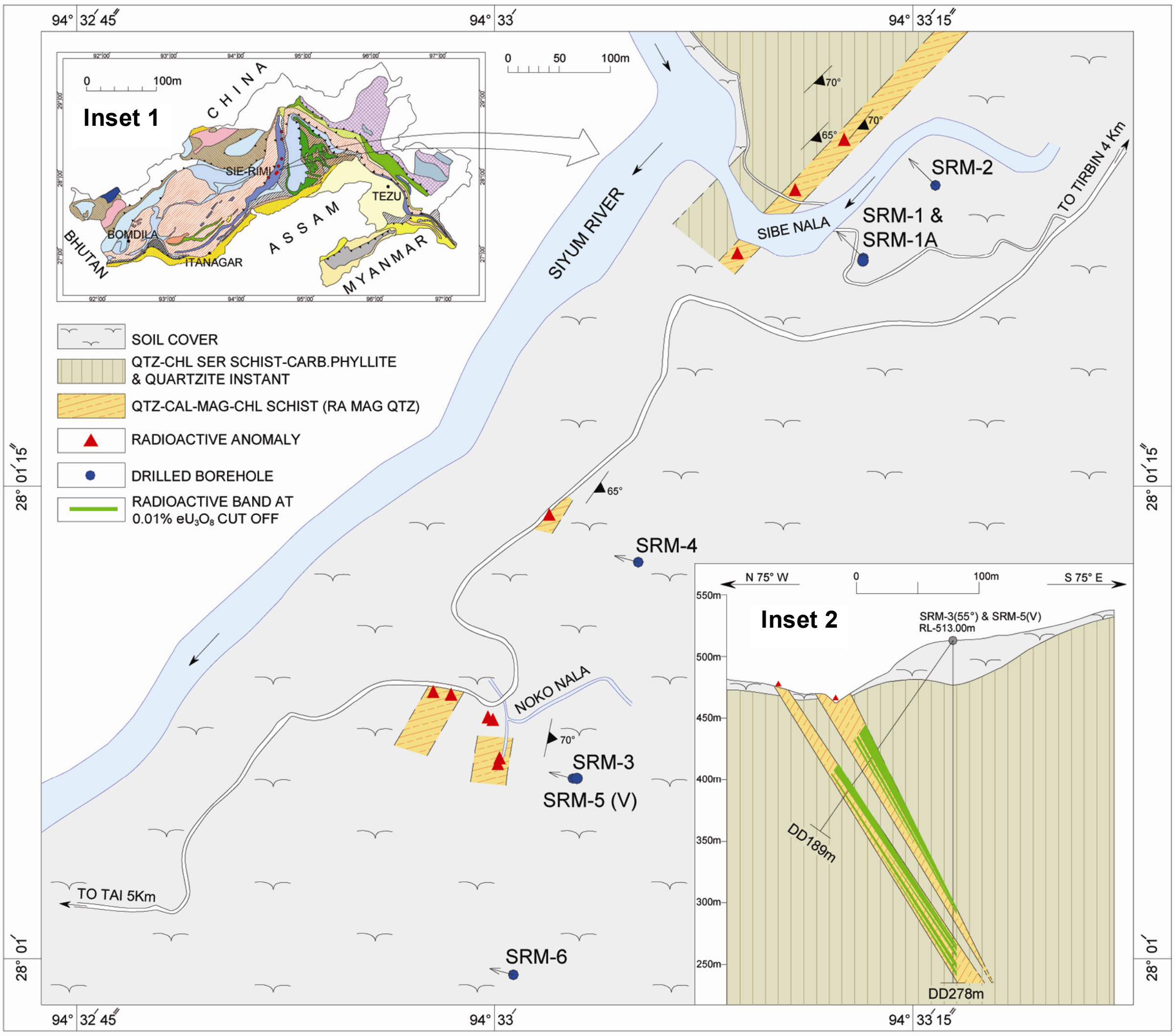

Figure 1. Geological map showing borehole locations in Sie Rimi-Noko nala area, West Siang district, Arunachal Pradesh. (Inset 1) Regional geological map of Arunachal Pradesh showing location of study area (geology after GSI[1]). (Inset 2) Transverse section through borehole nos SRM-3 and 5 in Sie Rimi-Noko Nala area.

the prominent wall-rock alterations and invariably are observed in the vicinity of uraniferous host rocks[2].

The present communication describes the details of subsurface uranium exploration in the Khetabari Formation of Bomdila Group, which is aimed at establishing a potential uranium resource in Arunachal Pradesh, Lesser Himalaya. Ground radiometric survey has established mineralized magnetite-rich rocks extending intermittently for over 700 m along strike from Sie Rimi in the northeast to Noko nala in the southwest; it continues intermittently further SW for over 3–4 km along a NNE/NE trend up to Kardo-Badak area with intermediate soil cover. Radiometric analysis of grab samples from radioactive horizon of Noko nala ($n = 6$) assayed <0.005–0.038% U_3O_8 and <0.010 to 0.069% ThO_2 (ref. 3). At Sie Rimi area grab samples ($n = 47$) have indicated 0.010% U_3O_8–0.073% U_3O_8, mostly with <0.010% ThO_2 (V. Rajagopalan and A. K. Pande, unpublished).

Reconnoitory drilling programme for investigating the subsurface continuation of uranium mineralization in the area around Noko nala-Sie Rimi on Tirbin-Tai road within the Khetabari Formation was commenced during 2012. A total of six inclined boreholes and one vertical borehole have been drilled so far over 850 m strike length and up to 300 m downdip (Figure 1). The boreholes intercepted mineralization with average grade ranging from 0.010% to 0.045% eU_3O_8 and thickness ranging from 1.0 to 8.1 m at a depth up to 265 m. Radiometric powder assay also confirms thorium-free uranium mineralization. Chemical analysis of the mineralized samples indicated values between 0.012% and 0.047% U_3O_8 (avg. 0.031%, $n = 11$) (M. Sharma and co-workers, unpublished).

The lithologies intercepted in the boreholes are variants of psammites, calcareous psammo-pelitic and pelitic rocks. The host rock is intensely foliated and has abundant foliation concordant discrete pyrite grains. Sulphide mineralization (~1–5% by visual estimation) in the form of pyrite and minor chalcopyrite was observed in the host rock throughout the borehole that occurs as thick band, minor dissemination, fine specks and

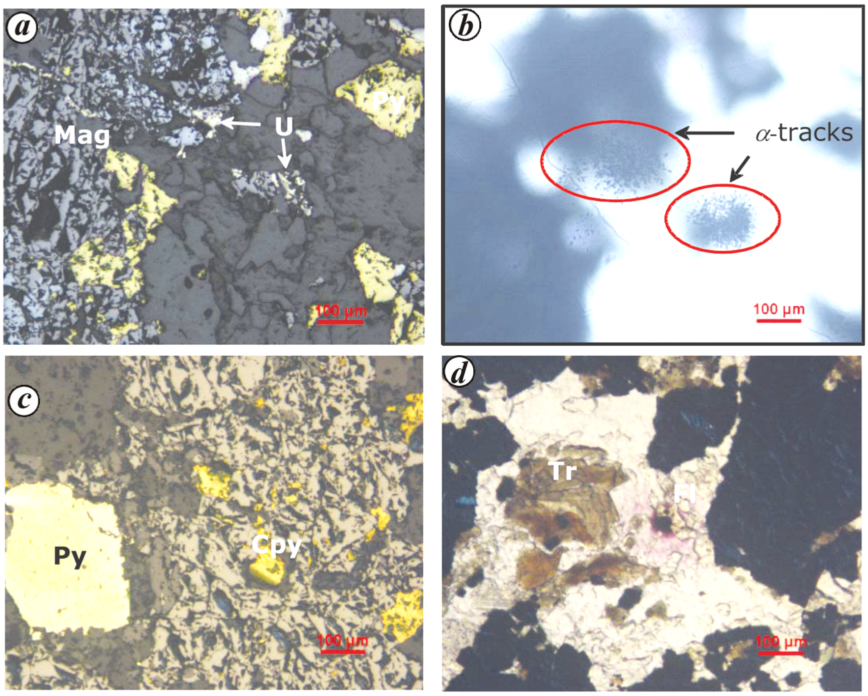

Figure 2. Photomicrographs of Sie Rimi-Noko nala area showing (***a***) minute grains of uraninite (U) in close association with magnetite (Mag), (***b***) dense α-tracks (encircled) on CN film corresponding to the uraninite grains, (***c***) assemblages of large euhedral grains of pyrite (Py), minute grains of chalcopyrite (Cpy) and martitized magnetite groundmass and (***d***) tourmaline (Tr) and fluorite (Fl) present in the ground mass.

thin stringers. Intense silicification, chloritization at places, carbonatization and sericitization were also observed.

The host rock of mineralization has been identified as magnetite-bearing calc schist with sulphides. The uranium-bearing mineral is petrographically identified as uraninite based on its reflectivity and dense α-tracts on CN film (Figure 2 *a* and *b*). The uraninite grains are associated with magnetite. Besides, autoradiography test using LR film indicates dispersed nature of uranium mineralization along foliation planes.

Petrographically, the major rock-forming minerals identified are calcite, plagioclase, feldspar, microcline, quartz, clinopyroxene, amphibole, almandine garnet, fluorite, epidote, tourmaline, apatite and chlorite. Magnetite, pyrite and traces of chalcopyrite are the major non-radioactive ore minerals in the order of abundance (Figure 2 *c*). Presence of tourmaline and fluorite, strongly points to the role of hydrothermal activity in uranium mineralization (Figure 2 *d*).

The following events might have occurred during the metamorphism and hydrothermal activity: Metamorphism of pre-existing sediments formed garnet and clinopyroxene. The early phases of hydrothermal activity, concurrent with metamorphism resulted in the formation of magnetite, pyrite and other base metals. Subsequent multiple phases of hydrothermal fluids, rich in CO_3^{2-}, F^-, B interacting with the metasediments precipitated calcite, apatite, fluorite and tourmaline. Finally, during retrograde metamorphism pyroxene was converted into hornblende, garnet to chlorite and plagioclase to epidote. These events of hydrothermal activity and retrograde metamorphism during the last phase, probably precipitated uranium.

The structural control and distinct hydrothermal alteration assemblages in the area are the best exploration guides for uranium mineralization. Multiple approaches involving geological investigations, subsurface exploration by drilling and radiometric studies have established significant uranium mineralization in the Sie Rimi area, West Siang district. This has also opened up a large area for uranium exploration in Arunachal Pradesh.

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