Siemens process. Alumino-thermic re-
duction should require even less energy
due to the considerably lower tempera-
ture of reduction. Further reduction of Al
content is required by slaggling or direc-
tional solidification.

   20.
2. Basu, P. K., Judson, K. C. and Lynn, S.,
   83, 864.
   Photovoltaic Specialists Conference,
5. Acharya, H. N., Banerjee, H. D. and Sen,
   S., Proceedings of the National Solar En-
   ergy Convention, India, 1978, p.396.
6. Bose, D. N., Govindacharyulu, P. A. and
   Banerjee, H. D., Solar Energy Mat.,
7. Bose, D. N. and Govindacharyulu, P. A.,
   Proceedings of Solar World Congress,
8. Dietl, J., Holm, C. and Siritl., Proceed-
   ings of 4th EC Photovoltaic Solar Energy
   Conference, D Reidel, Dordrecht, 1982,
   p. 941.
9. Khattak, C. P. and Schlund, F., Electro-
   chemical Society Meeting, San Fran-
   cisco, May 1983; Silicon Processing for
   Photovoltaics (eds Khattak, C. P. and
10. Bose, D. N., Haldar, A. R. and Chaud-
    huri, T. K., Proceedings of National So-
    lar Energy Convention (eds Ghosh, B.,
    Saha, S. K. and Sujoy Basu), Tata
    167–171.
11. Breakthrough in solar-grade silicon from
    rice hulls. Business Wire, Thermal Tech-
    nology, 27 September 2011; www.
    thermalotechnology.com

ACKNOWLEDGMENTS. We are grateful
to M.N.E.S., New Delhi for funding a project
on ‘Polycrystalline silicon from rice-husk’
and DST, Govt of West Bengal for a project
on ‘Low cost silicon for photovoltaic applica-
tions’ in which the work on quartzite was car-
ried out.

Received 5 December 2014; accepted 27 De-

cember 2014

D. N. Bose1,2*  
A. R. Haldar1  
T. K. Chaudhuri1

1Formerly at Materials Science Centre,
   Indian Institute of Technology
   Kharagpur,
   Kharagpur 721 302, India
2St. Xavier’s College,
   30 Mother Teresa Sarani,
   Kolkata 700 016, India
*For correspondence.
   e-mail: dwarkabose322@gmail.com

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

The Palaeoproterozoic low-grade meta-
sedimentary rocks of Bombdila 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 ura-
nium mineralization. Its basal sub-
division, the Khetabari Formation having
ferruginous, calcareous quartzitic meta-
sediments, graphitic/carbonaceous phyl-
lite, minor carbonates, chert and para-
ambphibolite and garnetiferous psammo-
pelites is bounded by the Permocarboni-
erous Gondwana equivalent Miri quartz-
tite in the east and with the 1.9-Ga-old
intrusive Bombdila/Ziro Gneisses in the

west. The rocks of the Khetabari Forma-
tion show multiple episodes of deforma-
tion. The F1 folds usually identifiable in
the psammitic rocks of the Khetabari
Formation are of isoclinal geometry. The
most pervasive planar fabric S1 is de-
veloped parallel to the axial plane of the F1
folds and in most places parallel to the S9
plane (original bedding plane), except
near the hinges. The F2 folds dipping at
moderate to steep angles towards SE
developed during the subsequent defor-
mation are superimposed over F1. Co-
axial refolding of the F1 folds producing
crystalization cleavage (S2) is found gener-
ally in the limbs of the isoclinal folds
within quartzo-feldspathic schists1. 

Effect of ductile shearing within the
psammo-pelites of the Khetabari Forma-
tion is evident by the presence of asym-
metric 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 ura-
nium occurrences in a variety of rocks
mainly of Palaeoproterozoic age. Con-
spicuously, uranium mineralization in all
these litothins is invariably associated
with sulphides. Sericitization, chloritiza-
tion, hematitization and silicification are

1216  CURRENT SCIENCE, VOL. 108, NO. 7, 10 APRIL 2015
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% \(\text{U}_3\text{O}_8\) and <0.010 to 0.069% \(\text{ThO}_2\) (ref. 3). At Sie Rimi area grab samples \((n = 47)\) have indicated 0.010% \(\text{U}_3\text{O}_8\)–0.073% \(\text{U}_3\text{O}_8\), mostly with <0.010% \(\text{ThO}_2\) (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% \(\text{U}_3\text{O}_8\) 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% \(\text{U}_3\text{O}_8\) (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 discordant 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 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.
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 \( \alpha \)-tracks on CN film (Figure 2a 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 2c). Presence of tourmaline and fluorite, strongly points to the role of hydrothermal activity in uranium mineralization (Figure 2d).

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 \( \text{CO}_2 \), \( \text{F} \), \( \text{B} \) 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.


Acknowledgements. We thank P. S. Parihar, Director, AMD, Hyderabad for permission to publish this paper. We also thank the scientists of Physics and Chemistry Laboratory, AMD, Shillong for providing the laboratory support.

Received 25 August 2014; accepted 12 February 2015

Bhaskar Basu*1
Manish Sharma*1
C. S. Guptä1
S. Thippeswamy1
A. V. Jeyagopal1
G. B. Joshi1
R. Mohanty1

1Atomic Minerals Directorate for Exploration and Research (AMD), Department of Atomic Energy (DAE), Shillong 793 019, India
2AMD, DAE, New Delhi 110 066, India
3AMD, DAE, Hyderabad 500 016, India
*For correspondence.
e-mail: bhaskarbasu.amd@gov.in

Figure 2. Photomicrographs of Sie Rimi-Noko nala area showing (a) minute grains of uraninite (U) in close association with magnetite (Mag), (b) dense \( \alpha \)-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.