Gold and uranium occurrences in quartz-pebble conglomerate of Iron Ore Group, Bagiyabahal–Baratangra area, Sundargarh district, Odisha, India

India is deficient in both gold and uranium resources. Almost one-third of the annual global mine production of ~2500 tonnes of gold is imported into India to fulfil the high gold consumption. Uranium is important for production of nuclear energy, more specifically to execute the country's ambitious programme to generate 20 GW of electricity by 2020.

In certain geological setting and age, uranium can deposit along with gold depending upon the extant provenances. Among these, quartz–pebble conglomerate (QPC) beds deposited over Archaean granite–greenstone basement during the Neoarchean transition to Paleoproterozoic Era assume importance because QPC is known the world over to host polymetallic gold and uranium mineralization along with pyrite, silver and platinum group metals. In eastern India, exploration carried out so far by the Atomic Minerals Directorate for Exploration and Research (AMD) has led to several discoveries of QPC-hosted uranium–gold mineralization in Archaean Iron Ore Group (IOG) and younger basins of Singhbhum–Orissa craton; for example, gold up to 382 ppb in Phuljhori Pahar–Balisura and 334 ppb in Sayamba–Taldih in uraniferous QPCs along the western and eastern margins of the Bonai Granitic Complex (BGC) in Koira IOG basin[1,2]; uraniferous QPC showing 200–700 ppb of gold in Dhosra Parbat and 400–800 ppb of gold at Turliga Parbat in Gorumahishani–Badampahar IOG basin[3]. At Moloyagiri–Bankhol IOG basin, 1.8 ppm of gold is reported from uraniferous QPC of Ramchandrapur area[3]. Recently, another significant gold mineralization (up to 29 ppm) has been

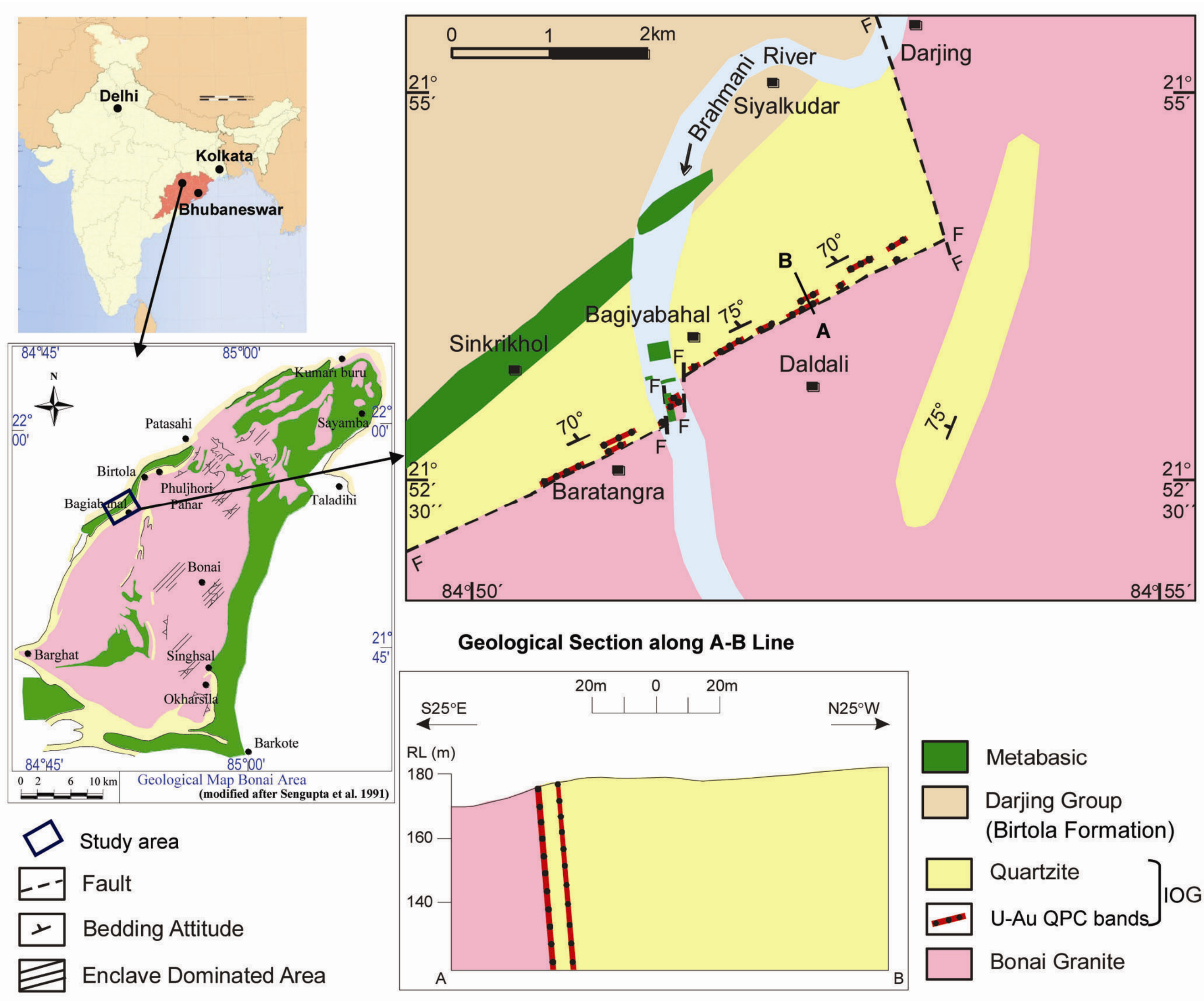

Figure 1. Geological map of Bagiyabahal–Baratangra area, Sundargarh district, Odisha, India showing locations of U–Au bearing quartz-pebble conglomerate (QPC) horizons (T.S. No. 73 C/13).

Figure 2. Field photographs of (***a***) radioactive basal QPC from Bagiyabahal area showing slightly stretched, sub-rounded to well-rounded vein quartz and smoky quartz pebbles embedded in siliceous and micaceous matrix and (***b***) basal QPC band showing radioactivity in Brahmani riverbed near Baratangra area, Sundargarh district, Odisha. (length of pen–14.2 cm). The QPC at Brahmani riverbed is more massive with mostly siliceous material in the matrix and smoky quartz pebbles as clast.

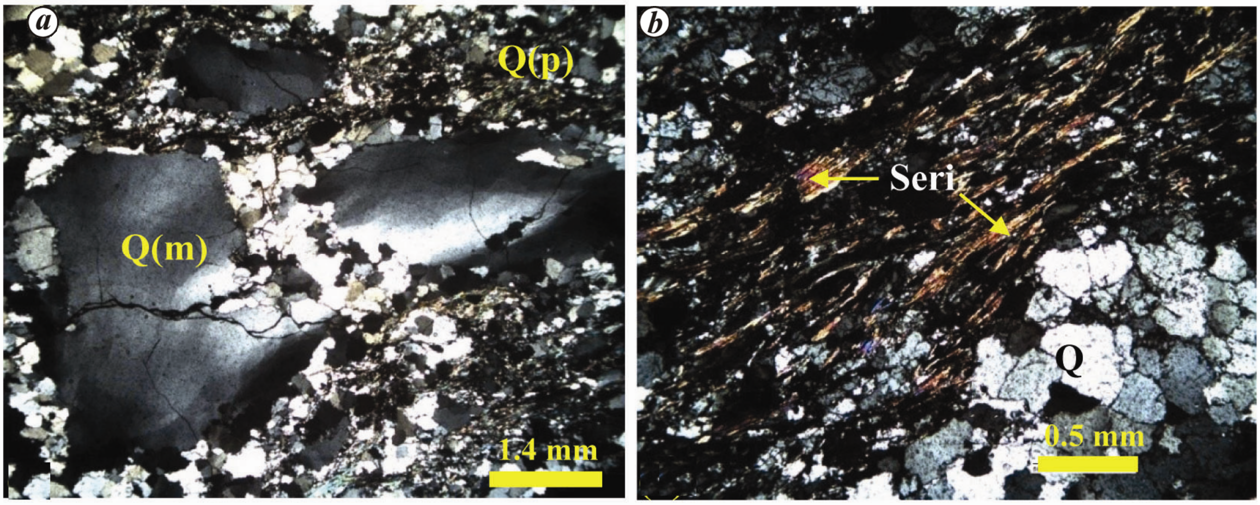

Figure 3. Photomicrographs of (***a***) basal radioactive QPC showing fractured monocrystalline quartz [Q(m)] with undulose extinction as well as strained polycrystalline quartz [*Q*(*p*)] and (***b***) crude schistosity of sericite (Seri) in the matrix suggesting the effects of post-depositional deformation and metamorphism, Bagiyabahal–Baratangra area, Sundargarh district, Odisha (under transmitted light, air and crossed nicols).

reported from the younger Mankarhachua basin[4]. Low- to medium-grade uranium mineralization is reported from all the above QPCs where the maximum radiometric U_3O_8 (β/γ) was 0.11% (ref. 2). Uranium minerals identified in these QPCs are mostly uraninite with occasionally brannerite, uranothorite, thucolite and pitchblende. Among the above occurrences, QPC of Bagiyabahal–Baratangra area significant due to its spatial dimension and continuity.

Radioactive oligomictic QPC bands were located by AMD at the base of the IOG as well as interlayered within IOG quartzite of Noamundi–Koira basin along the western margin of BGC in the Bagiyabahal–Baratangra area[5]. Recent mapping of Baratangra–Bagiyabahal–Daldali tract has defined QPC bands of ~3.2 km tract (Figure 1). In the study area, Bonai Granite Phase-I (3369 ± 57 Ma)[6] serves as the basement for the QPC-bearing volcano-sedimentary IOG succession, whereas Phase-II (3163 ± 126 Ma)[6] has an intrusive relation with the IOG rocks[7]. The IOG rocks are unconformably overlain by Birtola Formation of Darjing Group in the north.

In the study area, the 3.2 km long radioactive QPC horizon occurs from Baratangra in the west to the north of Daldali area in the east. The QPC horizon is affected by post-depositional faults. The basal QPC band is prominently exposed over the entire Baratangra–Daldali tract, whereas QPC bands interlayered with quartzite are exposed as discontinuous beds over approx. 800 m intermittently in Baratangra and 1 km in Bagiyabahal–Daldali areas. Thickness of the QPC bands varies from 30 cm to 1.5 m. The radioactive, interlayered QPC band to the north of Daldali is associated with pyrite. The QPC–quartzite succession trends in 65–245° direction with a sub-vertical to vertical (55–85°) dip towards NNW. Quartzite consists of

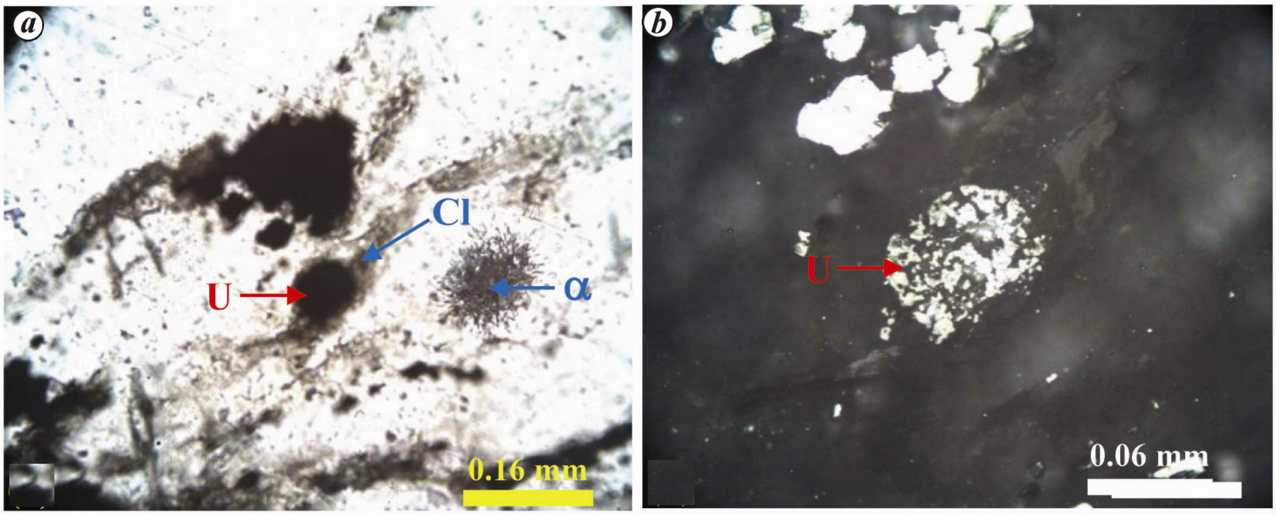

Figure 4. Photomicrographs of (***a***) radioactive QPC showing discrete, fine, sub-rounded detrital uraninite (U) grains [embedded in chloritic mass (Cl)] and the corresponding high-density alpha tracks (α) under transmitted light and (***b***) magnified view of corresponding uraninite (U) grain under reflected light in the matrix, Bagiyabahal–Baratangra area, Sundargarh district, Odisha. Both the images have been studied under plane polarized light [(***a***) is under air and (***b***) is under oil].

Table 1. Chemical analysis of gold vis-à-vis physical assay values from quartz-pebble conglomerate (QPC) bands, Bagiyabahal–Baratangra–Daldali tract

Sample no.	Locality	Lithology	Au* (ppb)	eU_3O_8	$U_3O_8(\beta–\gamma)$	$RaeU_3O_8$	ThO_2	Th/U	K (%)
				(ppm)					
BRTG/QPC/TB2	Baratangra	Basal QPC	<100	58	–	32	54	1.69	<0.5
BRTG/QPC/TB3			250	68	–	29	78	2.69	0.8
BRTG/QPC/TB4			<100	46	–	27	41	1.52	0.8
BRTG/QPC/TB5			<100	46	–	18	64	3.56	<0.5
BRTG/QPC/TB7			<100	–	–	–	–	–	–
BRTG/QPC/TB10			620	58	–	22	68	3.09	0.7
BRTG/QPC/TB11			2250	45	–	22	46	2.09	0.5
BRTG/QPC/TB13			<100	–	–	–	–	–	–
BRTG/QPC/TB14			<100	0.016%	0.010%	0.008%	0.016%	1.60	–
BRTG/QPC/TB15			100	–	–	–	–	–	–
BRTG/QPC/TB28			600	83	–	56	38	0.68	4.5
BRTG/QPC/TB29			500	–	–	–	–	–	–
BGBL/QPC/T5	Bagiyabahal		400	34	–	9	48	5.33	1.1
BGBL/QPC/T6			540	–	–	–	–	–	–
BGBL/QPC/T8			<100	–	–	–	–	–	–
BGBL/QPC/T16			<100	26	–	12	27	2.25	1.0
BGBL/QPC/T17			<100	–	–	–	–	–	–
BGBL/QPC/T21			220	23	–	8	23	2.87	1.2
BGBL/QPC/T22			390	42	–	12	55	4.58	1.2
BGBL/QPC/T23			580	65	–	32	67	2.09	0.7
BGBL/QPC/T23A	Bagiyabahal	Interlayered QPC	600	0.010%	<0.010%	<0.005%	0.012%	–	1.1
BGBL/QPC/66			200	0.031%	0.022%	0.022%	0.017%	0.77	–
DLDL/QPC/67	Daldali		230	0.016%	<0.010%	0.011%	0.010%	0.91	–
DLDL/QPC/69			410	68	–	34	67	1.97	1.1
BRTG/QPC/TB27	Baratangra		660	40	–	17	44	2.59	0.8

(*) Au is analysed by flame–AAS with a detection limit of 10 ppb and determination limit of 100 ppb for Au. (–) not determined.

Table 2. Physical assay values of QPC samples of Bagiyabahal–Baratangra–Daldali tract

Locality	QPC	Sample	eU_3O_8	$U_3O_8(\beta–\gamma)$	$RaeU_3O_8$	ThO_2	K (%)
Baratangra	Basal	25	17 ppm–0.026%	<0.010–0.023%	5 ppm–0.018%	16 ppm–0.018%	<0.5–4.5
Bagiyabahal		10	5–66 ppm	–	<5–32 ppm	<10–70 ppm	<0.5–1.2
Baratangra	Interlayered	2	40–50 ppm	–	14–17 ppm	44–72 ppm	0.6–0.8
Bagiyabahal		4	0.010–0.031%	<0.010–0.022%	<5 ppm–0.022%	0.012–0.023%	1.1
Daldali		3	60 ppm–0.016%	<0.010%	23 ppm–0.011%	67 ppm–0.010%	0.8–1.1

–, Not determined.

fine-grained quartz. Quartz grains are elongated and show serrated grain contact. Euhedral zircon inclusion is observed in quartz grains.

The QPC is matrix-supported, oligomictic comprising slightly stretched, sub-rounded to well rounded clasts of white vein quartz and greyish black-coloured smoky quartz pebbles (Figure 2). The matrix is composed mostly of siliceous and micaceous (sericite, chlorite, fuchsite, biotite and muscovite) minerals with ferruginous minerals (e.g. goethite) at places. Sericite and chlorite are the most dominant flaky minerals present in the matrix along with quartz and they show crude schistosity (S_1) which is parallel to the strike of the QPC–quartzite bedding (S_0). Pebble–matrix ratio is approx. 1 : 4 (by volume). In some places, prominent graded bedding is observed in the basal band of QPC (e.g. exposure at Brahmani river-section). Reduction in clast size (7.5–0.3 cm) and increase in the content of vein quartz clast are observed from the basal QPC to interlayered QPC lithounit.

Polished thin sections of radioactive QPC samples show evidence of post-depositional deformation and metamorphism indicated by the presence of fractured and slightly stretched monocrystalline quartz grains with strong undulose extinction (Figure 3 *a*), recrystallization of quartz along the grain boundary of quartz clasts and crude schistosity of sericite and quartz (Figure 3 *b*). Presence of strained, fine polycrystalline quartz, sericitization of feldspar, chloritization of biotite and chlorite with stains of ferruginous materials in the matrix also indicates post-depositional deformation and alterations. Sub-rounded and abraded uraninite grains (size 0.075 mm) (Figure 4 *b*) showing high-density alpha tracks on CN film (Figure 4 *a*) are closely associated with sub-rounded to rounded heavy minerals, viz. monazite, magnetite, pyrite, rutile, ilmenite, chromite and zircon (size varies from 0.07 to 0.28 mm) in the matrix, which suggests detrital origin of uraninite and other heavy minerals and paleo-placer-type deposition in the QPC. The heavy minerals indicate a mixed provenance for the QPC. The detrital uraninite, magnetite and chromite grains are mostly embedded in chlorite masses in the matrix which is squeezed and aligned along the grain boundary of the clasts during post-depositional deformation (Figure 4 *a*).

Estimation of Au in the QPC matrix was carried out at Chemical Laboratory of AMD, Jamshedpur. Samples of QPC were collected systematically from the trenches dug in the basal and interlayered QPC bands in Baratangra, Bagiyabahal and Daldali areas. Gold is estimated by treating the sample with aqua-regia followed by its separation with MIBK solvent extraction, and then determination using a flame atomic absorption spectrometer (Flame-AAS) with a detection limit of 10 ppb and determination limit of 100 ppb for Au. The above procedure is validated by analysing certified reference materials (CRM; DGPM-1 Au 0.730 ppm).

Chemical analysis revealed significantly higher Au concentration in the uraniferous QPC of Baratangra–Bagiyabahal–Daldali tract. Out of 25 samples, 9 samples analysed <100 ppb of Au and 16 samples ≥100 ppb in which Au content varies from 100 ppb to as high as 2.25 ppm (Table 1), which is significantly high compared to the crustal abundance of 2.5 ppb (ref. 8). The samples of basal QPC show Au in the range 100 ppb–2.25 ppm ($n = 11$) and the rest nine samples <100 ppb, whereas Au in interlayered QPC ranges from 200 to 660 ppb ($n = 5$).

Systematic sampling was carried out of the least weathered exposures of radioactive basal and interlayered QPC bands over 3.2 km strike length and 0.30–1.5 m width. The physical assay result of all the QPC samples (Table 2) shows eU_3O_8 in the range 5 ppm to 0.031%, <0.010%–0.023% U_3O_8 ($\beta–\gamma$), <5 ppm–0.022% $RaeU_3O_8$, <10 ppm–0.023% ThO_2 and <0.5%–4.5% K ($n = 44$). The mixed nature of assay value may be due to the syn-sedimentary mode of occurrence of the QPC. The equality in the $RaeU_3O_8$ and U_3O_8 ($\beta–\gamma$) values indicates that the samples are more or less in equilibrium. Th/U ratio ranges from 0.17 to 5.4 (avg 2.35; $n = 44$) and this lower Th/U ratio indicates the concentration of uranium in QPC under reducing condition compared to the average Th/U ratio of 4.0 in the crustal rocks. K% is due to the presence of biotite and sericite/muscovite in the matrix.

Tables 1 and 2 indicate that significant uranium and anomalous concentration of gold are present both in basal as well as interlayered QPC bands of Baratangra–Bagiyabahal–Daldali tract. Though the interlayered QPC band is relatively less developed in the area, its nearly equal U_3O_8 ($\beta–\gamma$) value (Table 2) as well as gold content compared to the basal QPC band shows its potentiality for further exploration. Gold is expected to be deposited as native, detrital flakes along with uranium- and thorium-bearing detrital grains from different sources as paleoplacers under anoxic condition in alluvial fan (braided stream) system. It may occur in pyrite as invisible form also. Whereas detrital uraninites are probably derived from Singhbhum Granite Batholith and/or Bonai Granite.

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The *Pollu* beetle in Andamans – do several lies make a truth?

In a recent issue of the *Indian Journal of Entomology*, Birah *et al.*[1] have attempted to defend the occurrence of *pollu* beetle, a pest of black pepper, in the Andaman and Nicobar Islands (A&N), India, as reported by them in an earlier article[2] in the same journal in 2011. Their most recent article[1] was in response to the counter to their first article by Prathapan[3] in the same journal, wherein he has critically reviewed the literature for the occurrence of the pest, found them wanting in understanding the pest damage, biology and nomenclature, faulted their methodology in assessing the damage and arriving at the insecticide dosage, etc. The authors' response[1] states that Prathapan's critical review made him conclude that the pest does not occur in the Andaman Islands. This admission of the carefulness of his approach is tantamount to accepting the conclusions made by him that the pest indeed does not occur in the A&N Islands. Further they add, 'All assumptions in this paper were based on earlier documentation.'[4,5] These two important 'earlier documentations', however, do not even find a mention in their original paper of 2011 and appear for their defence in their rejoinder after Prathapan's review[3]. However, they conveniently avoid making any mention of the meticulous work of their own Institute published as a research bulletin[6], which does not record the pest in the Islands. Thus (the paper of 2011) '... assumes that the berry damage is probably due to *pollu* beetle as had been earlier documented'. It is indeed surprising that a field experiment was carried out based on 'assumptions ... on earlier documentation' without verifying the veracity of occurrence of the reported insect, and also goes to the extent of stating 'assumes the berry damage is probably due to *pollu* beetle'. Their refuge and explicit authentication of their assumption is 'berry damage ... observed by its scientists (the authors of 2011 article) had been presented and reviewed in the Institute Research Council (ICAR-Central Island Agricultural Research Institute (CARI), Port Blair, A&N Islands) proceedings too'. While they bestow so much of faith only on some of the earlier works[4,5] as to make an 'assumption' of the pest's occurrence and 'damage probably due to *pollu* beetle', they seem to conveniently ignore some others[6] and strongly refute the claim of more recent work[3] stating that 'Perhaps (Prathapan's work) suffers from the required technical perfection to authentically rule out its non occurrence (in the islands)'. They further advocate in their conclusion that 'the occurrence of *pollu* beetle can thus be established only based upon a planned systematic study (on both spatial and temporal aspects) involving the beetle experts and entomologists working in the Islands who can monitor its field incidence throughout the year'. It seems rather strange that the very insect they claimed or rather 'assumed' to be causing up to 14.54%–18.56% berry damage[2] needs such a close and careful scrutiny to be even found to be present in the Islands.

The *pollu* (means hollow in Malayalam) beetle is the most important pest of black pepper (*Piper nigrum* L.) in Kerala and a few other parts of southern India, as the larvae directly infest the economically important part, the berry, and reduce the yield[7]. The common name of the pest derived from Malayalam has stuck (no other common names have been attributed to the pest in other languages), possibly indicating the limited distribution of the pest to parts of Kerala. Perusal of the literature since its first report[8] (as *Longitarsus nigripennis* (Motschulsky)) in 1919 also shows that the distribution of this insect is restricted to the southern Western Ghats and the adjoining plains in southern India[9], where pepper originated and is widely cultivated. Pepper has been later taken to several other areas in our country and is now mostly cultivated in the southern states, parts of North East India and A&N Islands[4]. The scientific name of the pest was changed in 2008 (to *Lanka ramakrishnai* Prathapan and Viraktamath, honouring the person who reported the pest first, Ramakrishna Ayyar[8]) according to some taxonomic nomenclature rules[9].

Distribution maps help one understand the species ranges and throw light on biogeography, species adaptations, species host range, phylogeny and the like, and are important from a biosystematics standpoint. Prathapan in this endeavour decided to look up the literature to understand the distribution of the *pollu* beetle that affects black pepper, on which he